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(54) Title: NOVEL AMP ACTIVATED PROTEIN KINASE

(57) Abstract

Polynucleotides of AMPK- α_1 , AMPK β and AMPK γ and polypeptides and biologically active fragments encoded thereby are provided. Vectors and host cells containing these polynucleotides are also provided. In addition, methods of preparing polypeptides and antibodies targeted against these polypeptides are provided.

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NOVEL AMP ACTIVATED PROTEIN KINASE

Background of the Invention

The present invention relates to novel AMP protein kinase subunits, to polynucleotides encoding these subunit 5 proteins and to antibodies which bind to these subunits.

The 5'-AMP-activated protein kinase (AMPK) was initially identified as a protein kinase regulating HMG-CoA reductase (Ferrer et al. (1985) *Biochem. Biophys. Res. Commun.* 132, 497-504). Subsequently, the AMPK was shown to 10 phosphorylate hepatic acetyl-CoA carboxylase (Carling et al. (1987) *FEBS Lett.* 223, 217-222) and adipose hormone-sensitive lipase (Garton et al. (1989) *Eur. J. Biochem.* 179, 249-254). The AMPK is therefore thought to play a key regulatory role in the synthesis of fatty acids and cholesterol.

15 The AMPK is believed to act as a metabolic stress-sensing protein kinase switching off biosynthetic pathways when cellular ATP levels are deleted and when 5'-AMP rises in response to fuel limitation and/or hypoxia (Corton et al. (1994) *Current Biology* 4, 315-324). Partial amino acid 20 sequencing of hepatic AMPK (Mitchellhill et al. (1994) *J. Biol. Chem.* 269, 2361-2364; Stapleton et al. (1994) *J. Biol. Chem.* 269, 29343-29346) revealed that it consists of 3 subunits, the catalytic subunit α (63 kDa), and two non-catalytic subunits, β (40 kDa) and γ (38 kDa).

25 The AMPK is a member of the yeast SNF1 protein kinase subfamily that includes protein kinases present in plants, nematodes and humans. The AMPK catalytic subunit, α , has a

- 2 -

strong sequence identity to the catalytic domain of the yeast protein kinase SNF1, which is involved in the induction of invertase (SUC2) under conditions of nutritional stress due to glucose starvation (Celenza, J.L. and Carlson, M. (1986) 5 *Science* 233, 1175-1180). Both snf1p and the AMPK require phosphorylation by an activating protein kinase for full activity. The sequence relationship between snf1p and AMPK led to the finding that these enzymes share functional similarities, both phosphorylating and inactivating yeast 10 acetyl-CoA carboxylase (Woods et al. (1994) *J. Biol. Chem.* 269, 19509-19516; Witters, L.A. and Watts, T.D. (1990) *Biochem. Biophys. Res. Commun.* 169, 369-376). The non-catalytic β and γ subunits of AMPK are also related to proteins that interact with snf1p; the β subunit is related to the SIP1/ SIP2 /GAL83 15 family of transcription regulators and the γ subunit to SNF4 (also called CAT-3) (Yang et al. (1994) *EMBO J.* 13, 5878-5886).

An isoform of the mammalian AMPK catalytic subunit has previously been cloned (Carling et al. (1994) *J. Biol. Chem.* 269, 11442-11448) and is referred to herein as AMPK α_2 . The 20 sequence of AMPK is disclosed in WO 94/28116. The AMPK α_2 does not complement SNF1 in yeast, indicating that their full range of functions are not identical.

A novel isoform of the mammalian AMPK catalytic subunit has now been identified and is referred to herein as 25 AMPK α_1 . In addition, full-length cDNAs for the mammalian AMPK β and AMPK γ subunits have now been cloned and polypeptides encoded thereby purified.

Summary of the Invention

30 Accordingly, a first aspect of the present invention provides an isolated polynucleotide which encodes mammalian AMPK α_1 or a sequence which hybridizes thereto with the proviso that the sequence does not hybridize to mammalian AMPK α_2 , as defined in Table 1 or Table 5 of WO 94/28116. In a preferred 35 embodiment, the polynucleotide comprises SEQ ID NO: 44. Also provided are vectors comprising such a polynucleotide, a host

- 3 -

cell transformed with such a vector and recombinant proteins encoded by such a polynucleotide.

In a second aspect, the present invention provides a method of producing mammalian AMPK α_1 , which comprises culturing 5 the cell including the polynucleotide of the first aspect of the present invention under conditions which allow expression of the polynucleotide encoding AMPK α_1 , and recovering the expressed AMPK α_1 .

In a third aspect, the present invention provides an 10 oligonucleotide probe of at least 10 nucleotides, the oligonucleotide probe having a sequence such that the probe hybridizes selectively to the polynucleotide of the first aspect of the present invention. By "hybridizes selectively" it is meant that the probe does not hybridize to a 15 polynucleotide encoding mammalian AMPK α_2 , as defined in Table 1 or Table 5 of WO 94/28116. The oligonucleotide probe may include at least about 5 contiguous nucleotides from the polynucleotide sequence which encodes amino acids 352-366. It will be understood by those of skill in the art that the 20 oligonucleotide probes according to the third aspect of this invention may be used in a number of procedures. These include the analysis of gene regulatory elements; the analysis of gene expression *in vivo*; and the identification of homologous mammalian and non-mammalian cDNAs including the associated 25 kinase-kinase.

In a fourth aspect, the present invention provides a substantially purified polypeptide encoded by a polynucleotide of the present invention or a biologically active fragment thereof with the proviso that the fragment is not present in 30 mammalian AMPK α_2 , as defined in Figure 3A of WO 94/28116. In a preferred embodiment, the purified polypeptide comprises at least a portion of SEQ ID NOs: 1-43. Also preferred are biologically active fragments comprising at least 8 contiguous amino acids from the sequence DFYLATSPPDSDLDDHHLTR (SEQ ID NO: 35 45). By "biologically active fragment" it is meant a fragment which retains at least one of the activities of native AMPK α_1 , which activities include (i) the ability to stimulate

- 4 -

phosphorylation of protein molecules; and (ii) the ability to mimic the binding of native AMPK α_1 to at least one antibody or ligand molecule.

It will be appreciated by those skilled in the art that a number of modifications may be made to the polypeptides and fragments of the present invention without deleteriously effecting the biological activity of the polypeptides or fragments. This may be achieved by various changes, such as sulfation, phosphorylation, nitration and halogenation; or by 10 amino acid insertions, deletions and substitutions, either conservative or non-conservative (e.g., D-amino acids, desamino acids) in the peptide sequence where such changes do not substantially alter the overall biological activity of the peptide. By conservative substitutions the intended 15 combinations are: G,A; V,I,L,M; D,E; N,Q; S,T; K,R,H; F,Y,W,H; and P, $\text{N}\alpha$ -alkylamino acids.

It is also possible to add various groups to the polypeptides or fragments of the present invention to confer advantages such as increased potency or extended half-life in 20 vivo, without substantially altering the overall biological activity of the peptide.

The mammalian AMPK α_1 polypeptide of the present invention may be used to identify compounds which regulate the action of this kinase. Such compounds are desirable since, for 25 example, they may be used to reduce the biosynthesis of cholesterol and fatty acids. They may also be used to inhibit the release of these from intracellular stores by HSL. In addition, they may be used to reduce cellular malonyl CoA levels and promote the β -oxidation of fatty acids by the 30 mitochondria.

Compounds may be screened for mammalian AMPK α_1 antagonist or agonist activity by exposing mammalian AMPK α_1 of the present invention to the compounds and assessing the activity of the mammalian AMPK α_1 . Suitable screening methods 35 for identifying compounds which regulate the activity of mammalian AMPK α_1 include any conventional assay systems for determining such effects. For example, a peptide containing a

- 5 -

serine residue exclusively phosphorylated by AMP protein kinase is incubated in the presence of a preparation of AMP protein kinase and a radiolabel such as gamma ^{32}P [ATP]. The reaction is allowed to proceed for a period of about 5 minutes and is 5 conveniently terminated by the addition of acid. The phosphorylated peptide is conveniently separated from unincorporated radiolabel by binding to a charged membrane following washing. The degree of phosphorylation of the peptide is a measure of the activity of the mammalian AMPK α_1 .

10 In addition, compounds may be screened for ability to regulate expression of mammalian AMPK α_1 in a cell by exposing the cell transformed with the polynucleotide of the first aspect of the present invention to the compound and assessing the level of expression of the polynucleotide encoding 15 mammalian AMPK α_1 . Suitable screening methods for identifying compounds which regulate expression of mammalian AMPK α_1 include those which involve the detection and/or determination of the amount of mammalian AMPK α_1 or messenger RNA that encodes mammalian AMPK α_1 or protein in the presence of the 20 relevant test compound.

As indicated above, the compounds which regulate activity of mammalian AMPK α_1 are considered to be of potential use in the treatment of, for example, hypercholesterolemia, hyperlipidemia, obesity, clinical syndromes associated with 25 hypoxia or ischemia (e.g., myocardial infarction, stroke), disorders of nutrition and diabetes mellitus.

In a fifth aspect, the present invention provides an antibody which binds selectively to a polypeptide according to the fourth aspect of this invention. By "binds selectively" it 30 is meant that the antibody does not bind to mammalian AMPK α_2 , as defined in Figure 3A of WO 94/28116. The antibody may be a polyclonal or monoclonal antibody. It will be understood that antibodies of the present invention may be used in a number of procedures. These include monitoring protein expression in 35 cells; the development of assays to measure kinase activity; and the precipitation of AMP protein kinase and associated proteins which may lead to characterization of these proteins.

Full-length cDNAs for the mammalian AMPK β and AMPK γ subunits have now been cloned. These clones have been used to characterize the tissue distribution of subunit mRNA and to express subunit protein in both bacteria and mammalian cells.

5 Identification of their complete sequences has also led to the identification of protein families for each of these non-catalytic subunits.

Accordingly, in a sixth aspect, the present invention provides an isolated polynucleotide which encodes mammalian AMPK β , the polynucleotide comprising a nucleic acid sequence of SEQ ID NO: 61. Also provided are vectors comprising such a polynucleotide, host cells transformed with such a vector and recombinant proteins encoded by such a polynucleotide.

In a seventh aspect, the present invention provides 15 a method of producing mammalian AMPK β which comprises culturing the cell including the polynucleotide of the sixth aspect of the present invention under conditions which allow expression of the polynucleotide encoding AMPK β and recovering the expressed AMPK β .

20 In an eighth aspect, the present invention provides a substantially purified polypeptide, the polypeptide having an amino acid sequence of SEQ ID NO: 62.

In a ninth aspect, the present invention provides an isolated polynucleotide which encodes mammalian AMPK γ , the 25 polynucleotide comprising a nucleic acid sequence of SEQ ID NO: 63. Also provided are vectors comprising such a polynucleotide, host cells transformed with such a vector and recombinant proteins encoded by such a polynucleotide.

In a tenth aspect, the present invention provides a 30 method of producing mammalian AMPK γ which comprises culturing the cell including the polynucleotide of the ninth aspect of the present invention under conditions which allow expression of the polynucleotide encoding AMPK γ and recovering the expressed AMPK γ .

35 In an eleventh aspect, the present invention provides a substantially purified polypeptide, the polypeptide comprising an amino acid sequence of SEQ ID NO: 64.

Detailed Description of the Invention

Mammalian AMPK, as isolated from rat and porcine liver, contains three polypeptide subunits, termed AMPK α , AMPK β and AMPK γ . The α subunit contains the kinase catalytic domain sequence and is highly homologous to several members of the SNF1 kinase family. Multiple isoforms of the α subunit have now been identified with α_1 being responsible for about 90% of the AMPK activity detected in liver extracts. In addition, it has now been established that full-length AMPK β and AMPK γ subunits are likewise homologous to two classes of proteins in *S. cerevisiae*. This extends information previously available from limited peptide sequence analysis and from smaller PCR-derived cDNAs (Stapleton et al. (1994) *J. Biol. Chem.* 269, 29343-29346). Further, by cDNA cloning and direct peptide sequencing it has been demonstrated which isoforms of AMPK β and AMPK γ subunits interact with the α_1 catalytic subunit in liver. Thus, it has now been found that these non-catalytic subunits, like the α subunit isoforms, have a wider tissue distribution, as evidenced by mRNA content of several rat tissues, than expected from the AMPK activity distribution previously reported by Gao et al. (1995) *Biochem. Biophys. Acta.* 1200, 73-82 and Davies et al. (1989) *Eur. J. Biochem.* 186, 123-128.

A novel isoform of the mammalian AMPK catalytic subunit has now been identified and is referred to herein as AMPK α_1 . The α_1 (548 residues) and α_2 (552 residues) isoforms of AMPK have 90% amino acid sequence identity within the catalytic core but only 61% elsewhere. The major differences in the α_1 and α_2 sequences occur in their COOH-terminal tails which suggests that they may interact with different proteins within this region.

It has now been found that the α_2 8.5 kb mRNA is most abundant in skeletal muscle with lower levels in liver, heart and kidney. In contrast, very low levels of the α_1 6 kb mRNA were found in all tissue except testis, where a low level of an uncharacterized 2.4 kb mRNA was observed. The low levels of α_1 mRNA explains why the α_1 isoform was more difficult to clone

than the α_2 isoform. The α_1 isoform of the AMPK catalytic subunit, however, accounts for approximately 94% or more of the SAMS peptide phosphotransferase activity of rat liver and is therefore the predominant active expressed hepatic isoform.

5 A series of synthetic peptides including analogues of proteins not known to be substrates for the AMPK were screened with partially purified enzyme (purified to the DE-52 step). These included the myosin light chains, ADR1, glycogen synthase and phospholemmann. The phospholemmann peptides tested were poor
10 substrates and not investigated further. The glycogen synthase peptide, PLSRTLSVAAKK (SEQ ID NO: 46) was phosphorylated in an AMP-dependent manner at approximately 40% of the rate of the SAMS peptide, however, this peptide is an excellent substrate for a number of protein kinases, including protein kinase C and
15 calmodulin dependent protein kinase II (Kemp, B.E. and Pearson, R.B. (1991) in *Protein Phosphorylation*, Hunter, T and Sefton, B.M. (eds) *Methods in Enzymology*, 200, 121-134). The myosin light chain peptides tested were phosphorylated with rates approximately 15% of the SAMS peptide. It was found that the
20 ADR1 peptides ADR1(225-234) and ADR1(222-234)^{P229} were phosphorylated at rates of approximately 50% of the SAMS peptide. Results from these experiments indicate that the ADR1(222-234)^{P229} peptide is phosphorylated with an apparent Km of approximately 3 μ M compared to 33 μ M for the SAMS peptide.

25 In view of the low Km of the ADR1(222-234)^{P229} peptide as a substrate for the AMPK, affinity purification of the enzyme with this peptide was attempted. Initially the peptide was coupled to CNBr-activated sepharose. Although the peptide linked sepharose bound the AMPK containing fractions the enzyme
30 could not be differentially eluted from contaminating proteins with salt gradients. In contrast when the ADR1(222-234)^{P229} peptide was coupled to Pharmacia HiTrap column the AMPK was bound very tightly and required 2 M NaCl plus 30% ethylene glycol to elute it. Because the enzyme bound so tightly to
35 this substrate affinity column it was possible to load the enzyme in buffer containing 0.5 M NaCl. The resultant purified AMPK consisted of a 63 kDa catalytic subunit and 40 kDa and 38

- 9 -

kDa subunits related to *sip2* and *snf4*, respectively. In some preparations the AMPK was associated with high molecular weight material that corresponded to non-muscle myosin as assessed by tryptic peptide sequencing. An apparent purification of up to 5 38,000 with a yield of 15% and a recovery of 90 μ g of enzyme was obtained. The fold purification may be an overestimate due to the presence of uncharacterized inhibitory material in the early fractions. The enzyme was not apparent on SDS-PAGE until the final step of purification. The avidity of the enzyme for 10 the peptide bound to the Pharmacia HiTrap resin was greater than could be expected from the free peptide binding to the enzyme (K_m 3 μ M). Since the peptide linked to sepharose did not bind the enzyme as tightly it seems reasonable that the enhanced binding is due in part to the aminohexanoic acid 15 linker between the peptide and the resin. In the case of the cAMP-dependent protein kinase there is a hydrophobic pocket between the D and G helices that is responsible for high affinity binding of the peptide inhibitor PKI. Since the ADR1(222-234)P229 peptide, LKKLTLRASFSAQ (SEQ ID NO: 47), is 20 linked through the amine residues on its N-terminus or Lys residues, it is possible that the hydrophobic linker group has been fortuitously juxtaposed to a hydrophobic pocket on the AMPK.

In the course of sequencing the porcine AMPK it was 25 found that the amino acid sequence of some peptides derived from the pig liver AMPK α subunit did not match those deduced from the rat liver cDNA sequence (Carling et al. (1994) *J. Biol. Chem.* 269, 11442-11448; Gao et al. (1995) *Biochem. Biophys. Acta.* 1200, 73-82). Therefore, the rat liver AMPK 30 catalytic subunit, α was purified and peptides accounting for 40% of the protein sequenced (222/548 residues, SEQ ID NOs: 27-43). Eight of the 16 peptides contained mismatched residues with the reported AMPK cDNA sequence, but did match the pig liver enzyme sequence (SEQ ID NOs: 13-26). Using RT-PCR and 35 cDNA library screening, a cDNA sequence of the rat hypothalamus enzyme was obtained that accounted for all of the peptide sequences of the purified rat liver AMPK catalytic subunit

- 10 -

containing mismatches. The cDNA sequence of this AMPK catalytic subunit has been named α_1 , since it corresponds to the purified enzyme and is clearly derived from a different gene than the previously cloned a sequence (now referred to as 5 α_2). The α_1 isoform of the AMPK catalytic subunit accounts for approximately 94% or more of the SAMS peptide phosphotransferase activity of rat liver and is therefore the predominant active expressed hepatic isoform. Despite sequencing multiple preparations of the AMPK catalytic subunit 10 from both pig and rat liver (SEQ ID NOS 13-26 and 27-43, respectively), no peptides were obtained that matched the α_2 isoform sequence.

Within the catalytic cores of the α_1 and α_2 isoforms, there is 90% amino acid identity but only 61% identity outside 15 the catalytic core. Strong homology between the α_1 and α_2 sequences in the vicinity of the substrate binding groove, inferred from the protein kinase crystal structure for positions P₅ to P₅, suggest that the substrate specificities will be related. The substrate anchoring loop (also called the 20 lip or activation loop) contains an insert FL¹⁷⁰ for α_1 , α_2 and snf1p that may provide a hydrophobic anchor for a P₃ or P₄ hydrophobic residue in the peptide substrate. There is also E¹⁰⁰ (E¹²⁷ in cAMP-dependent protein kinase) and D¹⁰³ available for a P₁ basic residue specificity determinant for both the α_1 , 25 α_2 and snf1p. Both isoforms contain a Thr-172 residue equivalent to Thr-197 in the cAMP-dependent protein kinase, which is likely to be phosphorylated and necessary for optimal activity. Since the major differences in the α_1 and α_2 sequences occur in their COOH-terminal tails they may interact 30 with different proteins within this region.

Northern blot analysis of the β and γ subunits revealed a complex pattern of expression. The β subunit mRNA was least abundant with similar levels across a range of tissues except brain, whereas the γ subunit mRNA was abundant 35 in heart, lung, skeletal muscle, liver and kidney. An earlier report on the tissue distribution of the AMPK activity had claimed that it was predominantly a liver enzyme (Davies et al.

- 11 -

(1989) *Eur. J. Biochem.* 186, 123-128). In view of the mRNA distribution of the α_1 and β subunits, the tissue distribution of the AMPK activity was reassessed. The kidney contained the highest specific activity with similar levels in the liver, 5 lung and heart and little, if any, activity in skeletal muscle. It is clear that the AMPK activity has a wider tissue distribution than appreciated heretofore, closely paralleling the distribution of α_1 mRNA and not that of α_2 mRNA. Using peptide specific antisera to α_1 (residues 339-358) and α_2 , 10 (residues 352-366) it was found that the α_2 immunoreactivity was predominant in the heart, liver and skeletal muscle where there is also the highest concentrations of α_2 mRNA. In contrast the α_1 immunoreactivity is widely distributed as is the less abundant α_1 mRNA. The antibody to α_2 recognized a 15 minor component in the purified α_1 preparation but sufficient amounts of this have not been obtained to determine whether it represents weak cross reactivity with a form of α_1 , an additional isoform of the AMPK or a low level contaminant of the α_1 preparation by the α_2 isoform. The antibody to α_2 does 20 not immunoprecipitate α_1 activity from affinity purified α_1 AMPK. Both α_1 and α_2 migrate on SDS-PAGE at approximately 63 kDa. It was also found that the liver α_2 immunoreactivity was not bound by the peptide substrate affinity column. This column specifically binds the α_1 isoform. Using immune 25 precipitation of the effluent from the peptide substrate affinity column with α_2 specific antibody it was found that the α_2 isoenzyme contained β and γ subunits and catalyzed the phosphorylation of the SAMS peptide. Immune precipitates of α_1 and α_2 showed variable activation by 5'-AMP ranging from 2-3 30 and 3-4 fold, respectively. There was also an approximate 60 kDa band recognized by the α_1 -specific antibody in tissue extracts from heart and lung. This band is not present in the purified liver enzyme and its relationship to the α_1 isoform is not yet known.

35 The proportion of SAMS peptide phosphotransferase activity bound to the peptide affinity column with a single pass varied (ranged 90-92%, n=7 and 74-86%, n=6 rat liver

- 12 -

preparations). With recycling, approximately 94% of the activity was bound to the column. The residual activity was attributable to α_2 isoform activity based on immunoprecipitation with the α_2 -specific antibody. However, 5 the amount of protein immunoprecipitated based on Coomassie blue staining indicated that there was substantially more α_2 protein than was expected from only 6% of the total SAMS peptide activity. The apparent specific activity of the 10 isolated rat hepatic AMPK α_2 isoform with either the SAMS peptide or acetyl CoA carboxylase as substrate was more than 20-fold lower than the AMPK α_1 isoform. This estimate is based on measurements using the α_2 enriched fraction (α_1 depleted) and quantitation by immunoblotting compared to bacterially expressed α_2 .

15 The specific activity of the purified α_2 isoform is not yet known in the absence of bound antibody. Based on the α_2 cDNA sequence, Carling et al. (1994) *J. Biol. Chem.* 269, 11442-11448 reported that a peptide specific antibody immunoprecipitated virtually all of the partially purified AMPK 20 activity from liver. The peptide used in their experiments, PGLKPHPERMPPLI (SEQ ID NO: 48), contains 8/15 residues that are identical (underlined) between α_1 and α_2 , so it seems reasonable that their polyclonal antisera may recognize both isoforms.

25 These experiments make clear that there is an isoenzyme family of AMPK α catalytic subunits, thus increasing the complexity of activity analysis. This also raises the question of what function the α_2 isoform has and whether α_2 associates with a specific subset of β and γ subunits. A significant fraction of the α_2 isoform mRNA has a 142 bp out- 30 of-frame deletion within its catalytic domain that would encode a truncated, non-functional protein (Gao et al. (1995) *Biochem. Biophys. Acta* 1200, 73-82; Verhoeven et al. (1995) *Eur. J. Biochem.* 228, 236-243). The close sequence relationship between the α_1 isoforms from pig, rat and human means that 35 there is strong conservation across species. Previously, it was reported that human liver does not contain AMPK mRNA (Aguan et al. (1994) *Gene* 149, 345-350). However, it is now clear that

- 13 -

α_2 mRNA was being probed for and not the dominant α_1 isoform mRNA. The gene encoding the human liver AMPK catalytic subunit reported on chromosome 1 is therefore the gene for the α_2 isoform whereas the gene for the α_1 isoform is located on 5 chromosome 5. The AMPK subunit genes have now been mapped predominantly to the following chromosomal locations: α_1 , 5p12; β , 5q24.1; and γ , 12q13.1.

Recent genome sequencing has revealed multiple isoforms of the non-catalytic γ and β subunits of the AMPK. 10 There appear to be at least three isoforms of the γ subunit in brain with γ_2 and γ_3 present, distinct from the rat liver γ_1 isoform. Human brain also contains multiple β subunit isoforms distinct from the rat liver β_1 isoform. The accession numbers for putative AMPK β and γ subunit isoforms are γ_2 , 15 M78939; γ_3 , R52308; β_2 , R20494 and β_3 , R14746. Thus, a potentially large subfamily of heterotrimeric AMPKs, based on various combinations of all three AMPK subunits, may be present.

The structural relationships between the AMPK and SNF1 20 kinase, as well as the presence of multiple isoforms, brings into focus a vista of questions concerning the diverse physiological roles of this new subfamily of protein kinases. Whereas the AMPK regulates lipid metabolism in hepatocytes under conditions of metabolic stress, its role in other 25 tissues, including the heart and kidney, are unknown. Recent studies have shown that the AMPK is activated during cardiac ischaemia, and the activation persists during reperfusion, possibly contributing to the ischaemia-driven decoupling of metabolism and cardiac mechanical function (Kudo et al. (1995) 30 *J. Biol. Chem.* 270, 17513-17520).

Regulation of cardiac acetyl-CoA carboxylase by AMPK plays an important role in the switching of cardiac metabolism between the use of glucose and fatty acids as oxidative fuel. In the β cell of the pancreas, where AMPK subunits are highly 35 expressed in islet cells, glucose availability rapidly regulates acetyl-CoA carboxylase through changes in AMPK-directed phosphorylation, suggesting strongly a role for AMPK

- 14 -

in stimulus-secretion coupling for insulin release. In addition to these metabolic roles, members of the SNF1 protein kinase subfamily appear to play important roles in development, with the *par-1* gene of *C. elegans* playing an essential role in 5 embryogenesis.

PCR amplification of pig and rat liver cDNA with degenerate oligonucleotides corresponding to selected AMPK β peptide sequences yielded two major PCR products (Stapleton et al. (1994) *J. Biol. Chem.* 269, 29343-29346). One product, a 10 rat 309 bp partial length cDNA, was used to screen a rat liver cDNA library, yielding a 1107 bp clone (SEQ ID NO: 61). The screening PCR probe corresponded to nt residues 279-588 of this sequence. This clone contains an open reading frame encoding for a 270 amino acid peptide (SEQ ID NO: 62), which contains 15 all of the 15 independent (some overlapping) peptide sequences obtained from extensive sequence analysis of the purified protein. The translational start methionine codon is assigned from the typical Kozak sequence present for a initiation codon and the lack of any other upstream in-frame methionine codons. 20 While no in-frame stop codon is present in this 5'-upstream sequence, a human expressed sequence tag (EST) cDNA (GenBank accession no. T78033) in the database contains such a stop codon preceding the same assigned methionine start. This reading frame, however, predicts a protein of 30,464 daltons, 25 well below the estimated molecular weight of 40 kDa evident on SDS gel electrophoresis.

In order to clarify the size of the protein product that could be synthesized from this cDNA, the AMPK β clone was expressed both in bacteria and mammalian cells. In both 30 expression systems, the protein product migrates at a higher than predicted molecular weight. When purified as a His⁶-tagged fusion protein from *E. coli*, the isolated protein migrates on SDS gels with an apparent molecular weight of about 43,000 Da (the same as the ovalbumin standard). This 35 corresponds to a AMPK β polypeptide product of 40 kDa with an additional 3 kDa daltons of fusion tag sequence derived from the pET vector. When expressed in mammalian cells from an HA-

- 15 -

tagged expression vector, two polypeptides are evident with the major product corresponding to a 40 kDa species (after correction for the size of the HA epitope tag). A second product of 42-43 kDa is also evident using this expression system. Taken together, these data demonstrate that the protein product of this AMPK β migrates on SDS-PAGE with an anomalously high molecular weight.

Comparison of the rat liver AMPK β sequence to the database reveals that it is highly homologous to three yeast proteins (Sip1p, Sip2p and Gal83p) and to two recently cloned human EST-cDNA sequences. This alignment, as gapped according to the sequence of the *S. cerevisiae* protein, Sip1p (Yang et al. (1992) *Science*, 257, 680-682), is most striking at the C-terminus of AMPK β and these yeast proteins.

The AMPK β subunit is a mammalian homolog of a class of proteins in yeast, represented by Sip1p/Sip2p/Gal83p. The GAL83 gene product is known to affect glucose repression of the GAL genes. All of these proteins have been shown to interact with the Snf1p protein kinase either in the 2-hybrid system or by immunoprecipitation. It has been proposed that these proteins serve as adaptors that promote the activity of Snf1p toward specific targets. Based on analysis of yeast mutants, it has been suggested that these proteins may facilitate interaction of Snf1p with unique and different targets. Of interest is the demonstration of a highly conserved domain of about 80 amino acids in the C-terminus of Sip1p/Sip2p/Gal83p, termed the ASC domain (association with Snf1p complex) (Yang et al. (1994) *EMBO J.* 13, 5878-5886). As studied in the 2-hybrid system, the ASC domain of both Sip1p and Sip2p interacts strongly with Snf1p. However, the interaction of Sip2p with Snf1p is not entirely lost on deletion of this domain, suggesting that the ASC domain is not solely responsible for this protein-protein interaction. A putative ASC domain is also highly conserved in the C-terminus of rat liver AMPK β (aa residues 203-270), suggesting that this region may be responsible, in part, for binding to the AMPK α subunit.

- 16 -

AMPK β , like Sip2p and Gal83p, is phosphorylated *in vitro* when associated with a catalytic subunit (AMPK α or Snf1p, respectively). Mutations of Gal83p can abolish most of the Snf1p kinase activity detectable in immune complexes, 5 precipitated with anti-Snf1p antibody. A Sip2p/E gal 83/E mutant shows reduced Snf1 protein kinase activity, that is restored following expression of either Sip2p or Gal83p LexA-fusion proteins in the mutant strain (Yang et al. (1994) EMBO J. 13, 5878-5886). Taken together, these data suggest the 10 possibility that AMPK β may also serve as an adaptor molecule for the AMPK α catalytic unit and will positively regulate AMPK activity.

AMPK β appears to have anomalous migration on SDS gels, with the polypeptide migrating at a M_r approximately 10 15 kDa larger than the size predicted from the cDNA. This slower migration is evident for both the bacterially expressed His⁶-fusion protein and for the protein expressed in COS7 cells. These observations suggest that higher orders of structure are responsible for the anomalous migration on SDS-PAGE. The AMPK 20 β subunit is autophosphorylated *in vitro*; this suggests that the two AMPK β bands expressed on transfection of mammalian cells with AMPK β cDNA may result from a similar post-translational modification giving rise to smaller mobility shifts. Interestingly, this aberrant migratory behavior of 25 AMPK β is similar to that of its yeast homolog, Gal83p. The LexA-fusion protein(s) of Gal83, as expressed in yeast, also migrate at greater than the expected molecular weight and display more than one band on SDS gels, consistent with the known phosphorylation of Gal83p by Snf1p. Mass spectrometry 30 analysis of the β -subunit indicates that the amino terminal glycine is myristylated and that the subunit is isolated in mono- and di- phosphorylated forms.

Using the MOPAC procedure and other PCR amplification protocols, a 192 bp cDNA corresponding to rat liver AMPK γ 35 sequence was obtained and used for library screening to obtain a partial length rat liver cDNA of approximately 1.3 kb. This sequence did not contain either a start methionine codon or all

- 17 -

the peptide sequences obtained from the purified protein. Attempts to extend this sequence to the 5'-end by the use of a primer extension library and 5'-RACE only succeeded in adding about 200 nt to this sequence without identification of the 5 start codon. A partial length rat cDNA was then used to screen a human fetal liver library, which did yield the full-length clone depicted in SEQ ID NO: 63. This clone contains a deduced amino acid sequence (SEQ ID NO: 64) corresponding to all of 22 independent (some overlapping) peptide sequences obtained from 10 the purified rat and porcine liver AMPK γ , confirming clonal identity.

A typical Kozak translation initiation sequence surrounds the assigned methionine start codon; this start is also in-frame with a 5'-upstream stop codon. The assigned 15 start methionine is followed by an open reading frame predicting a protein of 331 amino acids and of 37,546 Da, which corresponds to the molecular weight observed on SDS gel electrophoresis of the protein as purified from rat and porcine liver. Expression of a truncated rat AMPK γ cDNA (aa residues 20 33-331) and the full-length human AMPK γ (331 aa) in COS7 cells yields products consistent with the molecular weight predicted for each cDNA (34,081 and 37,577 daltons, respectively). The rat liver AMPK γ product expressed in bacteria also displayed the molecular weight predicted by the cDNA. Thus, unlike AMPK 25 β , there is no anomalous migration of the protein product of AMPK γ cDNA.

Comparison of the human and rat liver AMPK γ amino acid sequences to the database yields a significant alignment of this protein with the *S. cerevisiae* Snf4p. In addition, 30 human full-length cDNA of the present invention also aligns with several other human partial length EST-cDNA sequences from brain, breast, placenta, liver and heart, recently reported in the database. Inspection of these sequences reveals that there are multiple isoforms of the human AMPK γ 35 protein. There are likely also similar AMPK γ isoform families expressed in the rat and pig. This latter expectation is based on sequence analysis of 14 other MOPAC-derived partial AMPK γ

- 18 -

CDNA sequences, as identified on colony hybridization of the AMPK γ MOPAC products with 32 P-labeled degenerate oligonucleotides. These products showed at least two reproducible patterns of nucleotide heterogeneity within the 5 non-degenerate core.

Rat and human liver AMPK γ is a mammalian homolog of the *S. cerevisiae* Snf4p (CAT3) (Celenza et al. (1989) *Mol. Cell. Biol.*, 9, 5045-5054; Schuller, H.J. and Entian, K.D. (1988) *Gene*, 67, 247-257; Fields, S. and Song, O.K. (1989) 10 *Nature*, 340, 245-246). Snf4p was shown to interact with the Snf1p protein in the first reported use of the 2-hybrid system and also co-immunoprecipitates with it (Haygood, M.G. (1993) *Biotechniques* 15, 1084-1089). Indeed, on isolation of the Snf1p kinase from yeast, Snf4p, but not the other Snf1p- 15 interacting proteins, co-purifies in a 1:1 stoichiometry with the Snf1p polypeptide. Analysis of SNF4 mutants in yeast suggests that Snf4p also positively regulates the activity of its associated catalytic subunit, Snf1p. By analogy, our prediction is that AMPK γ will also have such a positive 20 influence on the AMPK α subunit.

Examination of the database reveals that, in addition to the homology of AMPK γ to Snf4p, there are 2 or 3 different human proteins highly homologous or identical to our human and rat liver AMPK γ sequences. However, some of these database 25 sequences, as predicted from EST-cDNAs in brain, heart, breast and placenta, are distinct from each other and from our clones; some, for example, have a C-terminal extension. This indicates that there is a mammalian isoform family of potential AMPK γ subunits, each perhaps with different tissue expression and 30 regulatory roles. It is suggests that these different gamma isoforms be designated γ_1 , γ_2 , γ_3 , ..., γ_n , as their full-length sequences are delineated. The rat liver/human liver AMPK γ sequence of the present invention is designated herein as AMPK γ_1 .

35 AMPK α catalytic unit is widely expressed in several rat tissues. AMPK β and AMPK γ sequences have a similar wide tissue expression. Two species of AMPK γ mRNA of 2.7 and 1.9

- 19 -

kb are evident in total mRNA preparations; only the latter is present in polyA⁺-RNA from rat liver, suggesting that the larger mRNA is an unprocessed precursor. Only a single mRNA species for AMPK β of 1.9 kb is evident. Both AMPK γ and 5 AMPK β mRNAs are highly expressed in kidney, white adipose tissue, lung and spleen, while AMPK γ mRNA appears to be more highly expressed in heart and brain. While detectable, the mRNA level for each subunit is relatively lower in skeletal muscle, lactating mammary gland and liver. In other studies, 10 high concentrations of mRNA have been found for both subunits in the rat Fao hepatoma cell and the Syrian hamster insulin-secreting HIT cell, cell lines that both express substantial levels of AMPK activity.

AMPK was first recognized as a protein kinase active 15 on enzymes of lipid metabolism (acetyl-CoA carboxylase, HMG Co-A reductase and hormone-sensitive lipase). However, as has been observed for the AMPK α subunit, the AMPK β and AMPK γ , subunits have wider tissue distribution than might be expected for a protein active only in the regulation of 20 lipid metabolism. While mRNAs for each are detectable in "classic" lipogenic tissues like liver, white adipose tissue and lactating mammary gland, high concentrations of mRNA in non-lipogenic tissues like heart, brain, spleen and lung, for example, suggest that these proteins have roles that extend 25 beyond the regulation of biosynthesis of fatty acids and sterols and fatty acid oxidation.

For example, the striking homology of all three subunits to yeast proteins that are involved in nutrient (glucose) responses suggests that the three mammalian proteins 30 may be involved in glucose (or other nutrient) regulation of gene expression in mammalian tissues or in other adaptive responses to a changing nutrient environment. In addition, AMPK may be a important "metabolic sensor" linked to oxidative fuel choice in the heart and to glucose sensing in the 35 pancreatic beta cell, perhaps being important for insulin secretion.

- 20 -

The following nonlimiting examples are provided to further illustrate the instant invention.

EXAMPLES

Example 1: Purification of AMPK Catalytic Subunit ($\alpha 1$)

5 Enzyme Purification

AMPK was purified from porcine liver. Liver (1 kg) was homogenized in 4,000 ml of buffer. A 2.5-7.0% (w/v) PEG 6000 fraction was prepared and the resultant fraction batched onto 1,500 ml of DEAE cellulose (Whatman, Clifton, NJ) and 10 eluted with buffer containing 0.25 M NaCl (2,000 ml). The eluate was chromatographed on 150 ml Blue Sepharose (Pharmacia, Uppsala, Sweden) and the AMPK eluted with buffer containing 1 M NaCl. The enzyme fraction was concentrated and desalted by 15 10% (w/v) PEG-6000 precipitation prior to chromatography by peptide substrate affinity chromatography. The peptide substrate affinity column was washed with the same buffer containing 0.1% (v/v) Triton X-100 and 0.5 M NaCl and the AMPK eluted with this buffer containing 2 M NaCl and 30% (v/v) ethylene glycol.

20 Protein kinase assays

The AMPK was assayed in accordance with procedures described by Davies et al. (1989) *Eur. J. Biochem.* 186, 123-128 using the SAMS peptide substrate, HMRSAMSGLHLVKRR-amide (SEQ ID NO: 49). The enzyme was diluted in diluting buffer (20 mM 25 HEPES pH 7.0, 0.1% (v/v) Triton X-100) prior to assay and the reactions were initiated by adding 10 ml diluted enzyme to the reaction mixture containing peptide substrate. The reactions were stopped by withdrawing 30 ml aliquots and applying to P81 papers in accordance with procedures described by Pearson, 30 R.B., Mitchelhill, K.I., and Kemp, B.E. (1993) in *Protein Phosphorylation: A Practical Approach*, Hardie, G.D. (ed) Oxford University Press, pp 265-291.

Peptide synthesis

Peptides were synthesized using an Applied Biosystems 430 synthesizer in accordance with procedures described by Pearson, R.B., Mitchelhill, K.I., and Kemp, B.E. (1993) in 5 *Protein Phosphorylation: A Practical Approach*, Hardie, G.D. (ed) Oxford University Press, pp 265-291. All peptides were purified by cation-exchange chromatography followed by reverse phase chromatography. Peptides were analyzed by quantitative amino acid analysis using a Beckman 6300 amino acid analyzer. 10 The peptide substrate affinity column was prepared by coupling the ADR1(222-234)²²⁹, peptide to a Pharmacia HiTrap N-hydroxysuccinamide ester activated superose column. This resin contains a 6-aminohexanoic acid spacer arm. The conditions of coupling were performed in accordance with manufacturer's 15 instructions with 10 mg peptide per 5 ml column and peptide coupling was monitored by reverse phase HPLC.

Example 2: Isolation of cDNA Encoding AMPK Catalytic Subunit ($\alpha 1$)**Peptide Sequencing**

20 Peptides were derived from rat and porcine $\alpha 1$ subunit of the AMPK, by *in situ* proteolysis in accordance with procedures described by Mitchelhill et al. (1994) *J. Biol. Chem.* 269, 2361-2364 and sequenced on either an Applied Biosystems 471A Protein Sequencer or a Hewlett Packard G1000A 25 Protein Sequencer.

Tissue Distribution Activity Studies

A 35% saturated ammonium sulfate fraction was prepared for each tissue, following homogenization in AMPK homogenization buffer (HB, 50 mM Tris-HCl pH 8.5, 250 mM 30 sucrose, 5 mM sodium pyrophosphate, 50 mM sodium fluoride, 1 mM EGTA, 1 mM EDTA, 1 mM DTT, 1 mM benzamidine, 1 μ g/ml soybean trypsin inhibitor and 0.2 mM phenylmethyl-sulfonylfluoride). The resultant pellet was resuspended in 5 ml HB and assayed for protein concentration. The AMPK was assayed in accordance 35 with procedures described by Mitchelhill et al. (1994) *J. Biol.*

- 22 -

Chem. 269, 2361-2364 with the following modifications: a final reaction volume of 120 μ l was used, enzyme aliquots (30 μ l) containing 1 μ g protein pre-diluted in 50 mM Tris-HCl pH 7.5 and 0.05% (v/v) Triton X-100 were used to initiate the 5 reaction. Three aliquots (30 μ l) were removed after 2, 4 and 6 min. Reactions were performed in duplicate \pm 5'-AMP (200 μ M), with a minus peptide substrate control. The specific activity of the enzyme was determined using linear rates of phosphorylation with the specific synthetic peptide substrate 10 SAMS. The AMPK was purified from rat or porcine liver as described in Example 1 using substrate affinity chromatography.

Isolation of AMPK cDNA

A radiolabelled cDNA (774bp) encoding porcine AMPK α_1 was used to screen a rat hypothalamus Zap II cDNA library 15 (Stratagene, La Jolla, CA) according to the manufacturer's instructions. Positives were plaque-purified on subsequent rounds of screening and phagemid from positive clones were rescued with helper phage (Stratagene). Screening of 7×10^6 plaques yielded three unique clones, the largest consisting of 20 an open reading frame, corresponding to AMPK α_1 (2-549).

The AMPK α_1 5' end was isolated using a Gibco 5'-RACE kit (Life Technologies, Grand Island, USA) with an α_1 specific primer to residues 41-48 and rat liver cDNA. Human AMPK α_1 (14-270) was isolated from fetal human liver cDNA primed with 25 sense and anti-sense partially degenerate oligonucleotides to α_1 peptide sequence by RT-PCR. Human AMPK α_1 , residues 291-448 is a partial length human liver cDNA clone obtained from the Lawrence Livermore National Laboratory (clone 78297, accession number T50799).

30 Northern Blotting

A rat multiple tissue Northern (MTN) blot (Clontech, Palo Alto, CA, USA) containing 2 mg of poly(A)+ RNA of individual tissues was probed with 32 P-labelled rat AMPK α_1 and α_2 cDNAs according to the instructions supplied.

- 23 -

Production of Anti-AMPK Antibodies

Polyclonal antibodies to AMPK α_1 and α_2 were prepared as follows. Peptides based on the predicted amino acid sequences of AMPK α_1 for residues 339-358 (DFYLATSPPD₅FLDDHHHLTR (SEQ ID NO: 50)) and AMPK α_2 for residues 352-366 (MDDDSAMHIPPGLKPH (SEQ ID NO: 51)) were synthesized and coupled to keyhole limpet hemocyanin (Sigma Chemical Co. St. Louis, MO, H-2133) via a cysteine residue added to the N-terminus of the peptide using the heterobifunctional reagent, N-succinimidyl-3-10 (2-pyridyldithio)propionate (Pharmacia, Uppsala, Sweden). New Zealand White rabbits were immunized with 2 mg peptide conjugate initially in 50% (v/v) Freund's complete adjuvant and in 50% (v/v) Freund's incomplete adjuvant for subsequent immunizations. Rabbits were boosted fortnightly with 2 mg 15 peptide conjugate and bled 7 days after booster injections. Anti-AMPK α_1 and α_2 peptide antibodies were purified by peptide affinity chromatography.

Western Blotting

Multiple rat tissue western blots were prepared as 20 follows. Rat tissues were homogenized in AMPK HB and a 2.5 - 7% polyethylene glycol 6000 fraction was prepared. The resultant pellet was resuspended in 5 ml HB and assayed for protein concentration. One hundred micrograms of each tissue fraction was analyzed by SDS PAGE (13% acrylamide gels); 25 transferred to nitrocellulose (Schleicher & Schuell, Dassel, Germany); and probed with 3 μ g/ml and 6 μ g/ml affinity purified AMPK α_1 and α_2 antibodies, respectively. Primary antibody was detected using anti-rabbit IgG antibody conjugated to horseradish peroxidase (DAKO, Carpinteria, CA, USA) and 0.032% 30 3,3' -diamino-benzidine (D-5637, Sigma) together with 0.064% H_2O_2 .

Purification of AMPK α_2

Affinity purified AMPK α_2 antibody (2 mg) was coupled to CNBr-activated Sepharose 4B (Pharmacia, Uppsala, Sweden) 35 according to the manufacturer's instructions. The unbound

- 24 -

fraction from the substrate affinity column was applied directly to the AMPK α_2 antibody column, washed with 5 volumes of PBS and eluted with 200 mM glycine buffer pH 2.5 and immediately neutralized.

5 EXAMPLE 3: Isolation of cDNAs Encoding AMPK Non-Catalytic Subunits

AMPK isolation and peptide sequencing

Porcine and rat liver AMPK was isolated. Peptide sequences derived from the rat liver beta (40 kDa) and gamma 10 (38 kDa) subunits were obtained after subunit separation by SDS gel electrophoresis, band elution and *in situ* protease digestion in accordance with procedures described by Mitchelhill et al. (1994) *J. Biol. Chem.* 269, 2361-2364 and Stapleton et al. (1994) *J. Biol. Chem.* 269, 29343-29346.

15 AMPK β subunit cDNA isolation

Peptide sequences derived from the AMPK β subunit were used to generate partial length AMPK β subunit cDNAs by the polymerase chain reaction (PCR) in accordance with procedures described by Gao et al. (1995) *Biochem. Biophys. Acta.* 1200, 20 73-82. One product, a 309 bp cDNA, was used to screen a rat liver λ ZAPII cDNA library (Stratagene). Filters were hybridized with 32 P-cDNA, labelled with alpha- 32 P-CTP (3000mCi/mmol, New England Nuclear) by random priming (Random Primer cDNA Labeling System, Gibco/BRL), in 50% formamide, 10X 25 Denhardt's, 1M NaCl, 50 mM Tris-Cl (pH 7.5), and 100 μ g/ml salmon sperm DNA at 42°C for 18 hours. They were then washed at room temperature 3 x 10 minutes and then at 55°C for 15 minutes. Autoradiography was for overnight at -80°C. All plates were lifted in duplicate and positive plaques were 30 purified through 3 additional rounds of plating and re-screening.

- 25 -

AMPK γ subunit cDNA isolation

Where peptide sequences are listed herein, the letters Y, H, N and R indicate regions of degeneracy. For the AMPK γ subunit, a 67 bp cDNA was generated by the MOPAC technique described by Lee, C.C. and Caskey, C.T., (1990) in *PCR Protocols*, (Innis, M.A. Gelfand, D.H., Srinsky, J.J., and White, T.J. editors), pp. 46-53, Academic Press, Inc., London. Degenerate PCR primers were synthesized corresponding to the N- and C- terminal sequences of a 17-amino acid rat liver AMPK γ peptide (VVDIYSKFDVINLAAEK (SEQ ID NO: 52)). The sequence of the sense primer was GCGGATCCGTNGAYATHTA (SEQ ID NO: 53) and the sequence of the antisense primer was CGGAATTCYTTCTNGCNGCNA (SEQ ID NO: 54). BamHI and EcoRI sites were added to the 5'-ends of these primers. The strategy was to create a non-degenerate nucleotide sequence corresponding to the middle portion of the peptide sequence that would be used in library screening. Total rat liver cDNA, prepared with oligo-dT and random hexamers (GIBCO/BRL pre-amplification kit), was used with PCR to amplify a 67-mer (including primers) oligonucleotide corresponding to a portion of the AMPK γ cDNA. The purified PCR product was digested with BamHI and EcoRI and ligated into pBluescript plasmid for transformation of DH5 α bacteria. Colony hybridization was employed to identify clones of interest; colonies were lifted from replica plates onto nitrocellulose filters. Following bacterial lysis and DNA denaturation, filters were probed with a mixture of two 32 P-end-labeled degenerate oligonucleotide probes corresponding to amino acid sequence (KFDVINLA (SEQ ID NO: 55)) internal to that of the two PCR primers. These oligonucleotides (#1: AARTTYGAYGTNATHAACTNGC (SEQ ID NO: 56); #2: AARTTYGAYGTNATHAACTTRGC SEQ ID NO: 57)) were added in a ratio of two parts oligo #1 to one part oligo #2 to reflect the degeneracy of the Leu codon. Positive colonies were identified and plasmid DNA isolated from each for sequence analysis. One such cDNA was chosen and the non-degenerate "core" 23-mer oligonucleotide sequence was then synthesized for use in library screening (CTCCAAGTTGATGTTATCAAACC (SEQ ID NO: 58)).

- 26 -

Screening of approximately 10^6 plaques with this probe, however, did not yield any positive clones.

The non-degenerate 23-mer cDNA was then used in conjugation with degenerate primers constructed from two other 5 peptide sequences to generate a larger AMPK γ cDNA by PCR. Both sense and antisense degenerate oligonucleotide primers corresponding to the peptide sequences, EELQIG (SEQ ID NO: 59) and FPKPEFM (SEQ ID NO: 60), were used together with the sense MOPAC-derived non-degenerate sequence to 10 generate all possible PCR products, using rat liver cDNA as template. The largest product (192 bp) obtained was subcloned in pCR-Script (Stratagene) and sequenced. This sequence, which actually had a predicted amino acid sequence corresponding to all three AMPK γ peptides used in the PCR strategy, was then 15 used for library screening, as above. Screening of 2×10^6 plaques with this larger PCR product yielded several positive clones; however, none of the rat cDNAs (1-1.3 kb) isolated corresponded to a full-length open reading frame. In an effort to extend the sequence to the 5'-end of the ORF, a primer 20 extension library was constructed using a AMPK γ -specific antisense primer (Stratagene; λ ZAPII). Additional screening of this library, while yielding some 5'-extended sequence, did not yield the start Met codon. The application of a 5'-RACE strategy with rat liver cDNA was also unsuccessful in attempts 25 at sequence extension, although a 5'-RACE product from porcine liver was obtained. The most 5' rat cDNA sequence (520 bp) was then used to screen a human fetal liver library, which yielded a full-length AMPK γ cDNA.

Plasmid Preparation and DNA sequencing

30 Plasmid DNA was prepared using Qiager Mini- or Midi- columns (Chatsworth, CA) according to the manufacturer's instructions. DNA was sequenced, with vector or gene-specific primers, using an Applied Biosystems Prism(tm) (Foster City, CA) ready reaction Dye Deoxy Terminator Cycle Sequencing kit, 35 and cycled in a Perkin-Elmer PCR Thermocycler, according to the manufacturers' instructions. Dye terminators were removed from

- 27 -

the resulting sequence reactions using a Centri-Step column (Princeton Separations, Inc.). The purified sequencing reactions were then dried in a Speed-Vac and analyzed on an automated DNA sequencer (Applied Biosystems Model 373).

5 Bacterial Expression of cDNAs

Full-length rat AMPK β subunit cDNA and a partial length rat AMPK γ (aa 33-331) subunit cDNA were expressed in *E. coli* using the pET vector system, which introduces polyhistidine (His6) and T7 fusion epitope tag sequences 10 (Novagen, Madison, WI). Bacterial expression was induced with 1.0 mM IPTG at 37°C for 2 hours. Expressed protein was detected by both Coomassie blue staining and immunoblotting with anti-T7 monoclonal antibody (Novagen). The fusion proteins were purified from the inclusion bodies of bacteria by 15 nickel affinity chromatography under denaturing conditions. His6-AMPK β or His6-AMPK γ were solubilized from the inclusion bodies in 6 M urea, according to manufacturer's instructions. After sample application, the column was washed extensively with Tris-Cl (20 mM; pH 7.9), 0.5 M NaCl (0.5 M), imidazole (20 mM) and urea (6 M). The His6-protein was eluted with the same 20 buffer containing 300 mM imidazole.

Cellular expression of cDNAs

Full-length rat AMPK β cDNA, a partial length rat AMPK γ (aa 33-331) and full-length human AMPK γ subunit cDNAs were 25 also expressed in COS7 cells. cDNAs were cloned into a pMT2 vector in-frame with a hemagglutinin (HA) epitope tag (pMT2-HA). Transfection was done using Lipofectamine reagent (Gibco/BRL), according to the manufacturer's general protocol. Cells were plated at 3×10^5 /well in 6 well plates in DMEM 30 containing 10% fetal calf serum and penicillin/streptomycin. The following day, the cells were switched to serum-free, antibiotic-free DMEM and then lipofectamine-DNA conjugates (2 μ g of DNA; 10 μ l lipofectamine per well) diluted in the same medium were added. After 5 hours incubation at 37°C, an equal 35 volume of medium containing 20% fetal calf serum was added to each well. The following morning, the medium was switched to

- 28 -

the original cell medium. Cells were harvested 48 hours after transfection. After washing with PBS, cells were lysed in a buffer containing Tris-Cl (50 mM; pH 7.5), NaCl (100 mM), NaF (50 mM), NaPP_i (5 mM), EDTA (1 mM), DTT (2 mM) and NP-40 (0.5%) with several protease inhibitors.

For complete lysis, cells were placed on ice for 15 minutes followed by scraping and vigorous vortexing (15 seconds) of the lysate. After clearing of debris by brief centrifugation, this lysate was used for SDS gel 10 electrophoresis and immunoblotting. Blots were probed with an anti-HA monoclonal antibody (derived from the 12CA5 hybridoma line). After secondary probing with an anti-mouse IgG-peroxidase antibody, blots were developed by ECL (Amersham).

Northern Blot Analysis

15 Total RNA was isolated from the tissues of male Sprague-Dawley rats (150-200 grams body weight; Charles River) or from the lactating mammary gland of female rats using a guanidium isothiocyanate-lithium chloride method. RNAs were fractionated on 1% agarose/formaldehyde gels with capillary 20 transfer to nitrocellulose (MSI). cDNA probes were labelled by random priming.

Hybridization was carried in 5x Denhardt's, 0.2 M Tris (pH 7.4), 1M NaCl and 0.1 mg/ml salmon sperm DNA at 42°C for 20 hours. Filters were washed sequentially with 2X SSPE/0.1% SDS 25 (room temperature; 2 x 15 minutes), 0.2 X SSPE/0.1% SDS (room temperature; 2 x 15 minutes) and with 0.2X SSPE/0.1% SDS (55°C; 2 x 15 minutes). Autoradiography on Kodak XAR film with enhancing screens was at -80°C for 18-48 hours.

DNA Sequence Analysis and DNA sequences

30 DNA sequences were analyzed using MacVector(r) and the GCG software package. Sequences were compared to the data base using BLAST and GCG; amino acid alignments were made using the Pileup program of GCG. Sequences were formatted using an Excel(r) macro. The DNA sequences described herein have been 35 deposited in the GenBank with the following accession numbers: rat liver AMPK β (U42411), rat liver AMPK γ (U42413) and human fetal liver AMPK γ (U42412).

- 29 -

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT: Dartmouth College, St. Vincent's Institute of Medical Research, Kemp et al.

(ii) TITLE OF INVENTION: Novel AMP Activated Protein Kinase

(iii) NUMBER OF SEQUENCES:

(iv) CORRESPONDENCE ADDRESS:

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(F) ZIP: 08002

(v) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: DISKETTE, 3.5 INCH, 1.44 Mb STORAGE

(B) COMPUTER: IBM 486

(C) OPERATING SYSTEM: WINDOWS FOR WORKGROUPS

(D) SOFTWARE: WORDPERFECT 5.1

(vi) CURRENT APPLICATION DATA:

(A) APPLICATION NUMBER: Not yet assigned

(B) FILING DATE: Herewith

(C) CLASSIFICATION:

(vii) PRIOR APPLICATION DATA:

(A) APPLICATION NUMBER: PN7450

(B) FILING DATE: 8 JAN 1996

(viii) ATTORNEY/AGENT INFORMATION:

(A) NAME: Jane Massey Licata

(B) REGISTRATION NUMBER: 32,257

- 30 -

(C) REFERENCE/DOCKET NUMBER: DC-0028

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(A) TELEPHONE: (609) 779-2400

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(2) INFORMATION FOR SEQ ID NO: 1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 345

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

MET	ALA	GLU	LYS	GLN	LYS	HIS	GLY	ARG	VAL	LYS	ILE	GLY	HIS	TYR
1					5					10				15
ILE	LEU	GLY	ASP	THR	LEU	GLY	VAL	GLY	THR	PHE	GLY	LYS	VAL	LYS
					20					25				30
VAL	GLY	LYS	HIS	GLU	LEU	THR	GLY	HIS	LYS	VAL	ALA	VAL	LYS	ILE
					35					40				45
LEU	ASN	ARG	GLN	LYS	ILE	ARG	LEU	ASP	VAL	VAL	GLY	LYS	ILE	ARG
					50					55				60
ARG	GLU	ILE	GLN	ASN	LEU	LYS	LEU	PHE	ARG	HIS	PRO	HIS	ILE	ILE
					65					70				75
LYS	LEU	TYR	GLN	VAL	ILE	SER	THR	PRO	SER	ASP	ILE	PHE	MET	VAL
					80					85				90
MET	GLU	TYR	VAL	SER	GLY	GLY	GLU	LEU	PHE	ASP	TYR	ILE	CYS	LYS
					95					100				105
ASN	GLY	ARG	LEU	ASP	GLU	LYS	GLU	SER	ARG	ARG	LEU	PHE	GLN	GLN
					110					115				120
ILE	LEU	SER	GLY	VAL	ASP	TYR	CYS	HIS	ARG	HIS	MET	VAL	VAL	HIS
					125					130				135
ARG	ASP	LEU	LYS	PRO	GLU	ASN	VAL	LEU	LEU	ASP	ALA	HIS	MET	ASN
					140					145				150
ALA	LYS	ILE	ALA	ASP	PHE	GLY	LEU	SER	ASN	MET	MET	SER	ASP	GLY
					155					160				165
GLU	PHE	LEU	ARG	THR	SER	CYS	GLY	SER	PRO	ASN	TYR	ALA	ALA	PRO
					170					175				180
GLU	VAL	ILE	SER	GLY	ARG	LEU	TYR	ALA	GLY	PRO	GLU	VAL	ASP	ILE
					185					190				195
TRP	SER	SER	GLY	VAL	ILE	LEU	TYR	ALA	LEU	LEU	CYS	GLY	THR	LEU
					200					205				210
PRO	PHE	ASP	ASP	ASP	HIS	VAL	PRO	THR	LEU	PHE	LYS	LYS	ILE	CYS
					215					220				225
ASP	GLY	ILE	PHE	TYR	THR	PRO	GLN	TYR	LEU	ASN	PRO	SER	VAL	ILE
					230					235				240
SER	LEU	LEU	LYS	HIS	MET	LEU	GLN	VAL	ASP	PRO	MET	LYS	ARG	ALA
					245					250				255
THR	ILE	LYS	ASP	ILE	ARG	GLU	HIS	GLU	TRP	PHE	LYS	GLN	ASP	LEU
					260					265				270

- 31 -

PRO	LYS	TYR	LEU	PHE	PRO	GLU	ASP	PRO	SER	TYR	SER	SER	THR	MET
275									280					285
ILE	ASP	ASP	GLU	ALA	LEU	LYS	GLU	VAL	CYS	GLU	LYS	PHE	GLU	CYS
290									295					300
SER	GLU	GLU	GLU	VAL	LEU	SER	CYS	LEU	TYR	ASN	ARG	ASN	HIS	GLN
305									310					315
ASP	PRO	LEU	ALA	VAL	ALA	TYR	HIS	LEU	ILE	ILE	ASP	ASN	ARG	ARG
320									325					330
ILE	MET	ASN	GLU	ALA	LYS	ASP	PHE	TYR	LEU	ALA	THR	SER	PRO	PRO
335									340					345

(2) INFORMATION FOR SEQ ID NO: 2:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 11

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

ASP SER PHE LEU ASP ASP HIS HIS LEU THR ARG

1 5 10

(2) INFORMATION FOR SEQ ID NO: 3:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 56

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

PRO	HIS	PRO	GLU	ARG	VAL	PRO	PHE	LEU	VAL	ALA	GLU	THR	PRO	ARG
1									10					15
ALA	ARG	HIS	THR	LEU	ASP	GLU	LEU	ASN	PRO	GLN	LYS	SER	LYS	HIS
									20	25				30
GLN	GLY	VAL	ARG	LYS	ALA	LYS	TRP	HIS	LEU	GLY	ILE	ARG	SER	GLN
									35	40				45
SER	ARG	PRO	ASN	ASP	ILE	MET	ALA	GLU	VAL	CYS				
									50	55				

(2) INFORMATION FOR SEQ ID NO: 4:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 70

(B) TYPE: Amino acid

- 32 -

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

ARG	ALA	ILE	LYS	GLN	LEU	ASP	TYR	GLU	TRP	LYS	VAL	VAL	ASN	PRO
1				5					10					15
TYR	TYR	LEU	ARG	VAL	ARG	ARG	LYS	ASN	PRO	VAL	THR	SER	THR	PHE
				20					25					30
SER	LYS	MET	SER	LEU	GLN	LEU	TYR	GLN	VAL	ASP	SER	ARG	THR	TYR
				35					40					45
LEU	LEU	ASP	PHE	ARG	SER	ILE	ASP	ASP	GLU	ILE	THR	GLU	ALA	LYS
				50					55					60
SER	GLY	THR	ALA	THR	PRO	GLN	ARG	SER	GLY					
				67					70					

(2) INFORMATION FOR SEQ ID NO: 5:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 64

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

SER	ILE	SER	ASN	TYR	ARG	SER	CYS	GLN	ARG	SER	ASP	SER	ASP	ALA
1				5					10					15
GLU	ALA	GLN	GLY	LYS	PRO	SER	GLU	VAL	SER	LEU	THR	SER	SER	VAL
				20					25					30
THR	SER	LEU	ASP	SER	SER	PRO	VAL	ASP	VAL	ALA	PRO	ARG	PRO	GLY
				35					40					45
SER	HIS	THR	ILE	GLU	PHE	PHE	GLU	MET	CYS	ALA	ASN	LEU	ILE	LYS
				50					55					60
ILE	LEU	ALA	GLN											

(2) INFORMATION FOR SEQ ID NO: 6:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 242

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

GLY	HIS	TYR	ILE	LEU	GLY	ASP	THR	LEU	GLY	VAL	GLY	THR	PHE	GLY
1				5					10					15
LYS	VAL	LYS	VAL	GLY	LYS	HIS	GLU	LEU	THR	GLY	HIS	LYS	VAL	ALA
				20					25					30
VAL	LYS	ILE	LEU	ASN	ARG	GLN	LYS	ILE	ARG	SER	LEU	ASP	VAL	VAL
				35					40					45
GLY	LYS	ILE	ARG	ARG	GLU	ILE	GLN	ASN	LEU	LYS	LEU	PHE	ARG	HIS

- 33 -

50	55	60
PRO HIS ILE ILE LYS LEU TYR GLN VAL	ILE SER THR PRO SER	ASP
65	70	75
ILE PHE MET VAL MET GLU TYR VAL SER	GLY GLY GLU LEU PHE	ASP
80	85	90
TYR ILE CYS LYS ASN GLY ARG LEU ASP	GLU LYS GLU SER ARG	ARG
95	100	105
LEU PHE GLN GLN ILE LEU SER GLY VAL	ASP TYR CYS HIS ARG	HIS
110	115	120
MET VAL VAL HIS ARG ASP LEU LYS PRO	GLU ASN VAL LEU LEU	ASP
ALA HIS MET ASN ALA LYS ILE ALA ASP	PHE GLY LEU SER ASN	MET
125	130	135
MET SER ASP GLY GLU PHE LEU ARG THR	SER CYS GLY SER PRO	ASN
140	145	150
TYR ALA ALA PRO GLU VAL ILE SER GLY	ARG LEU TYR ALA GLY	PRO
155	160	165
GLU VAL ASP ILE TRP SER SER GLY VAL	ILE LEU TYR ALA LEU	LEU
170	175	180
CYS GLY THR LEU PRO PHE ASP ASP ASP	HIS VAL PRO THR LEU	PHE
185	190	195
LYS LYS ILE CYS ASP GLY ILE PHE TYR	THR PRO GLN TYR LEU	ASN
200	205	210
PRO SER VAL ILE SER LEU LEU LYS HIS	MET LEU GLN VAL ASP	PRO
215	220	225
MET LYS ARG ALA THR ILE LYS ASP ILE	ARG GLU HIS GLU TRP	PHE
230	235	240
LYS GLN		

(2) INFORMATION FOR SEQ ID NO: 7:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 55

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

GLU ALA LEU LYS GLU VAL CYS GLU LYS	PHE GLU CYS SER GLU GLU	
1 5	10	15
GLU VAL LEU SER CYS LEU TYR ASN ARG	ASN HIS GLN ASP PRO LEU	
20	25	30
ALA VAL ALA TYR HIS LEU ILE ILE ASP	ASN ARG ARG ILE MET ASN	
35	40	45
GLU ALA LYS ASP PHE TYR LEU ALA THR	SER	
50	55	

(2) INFORMATION FOR SEQ ID NO: 8:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 9

- 34 -

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

PHE LEU ASP ASP HIS HIS LEU THR ARG

1 5

(2) INFORMATION FOR SEQ ID NO: 9:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 56

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

PRO HIS PRO GLU ARG VAL PRO PHE LEU VAL ALA GLU THR PRO ARG			
1	5	10	15
ALA ARG HIS THR LEU ASP GLU LEU ASN PRO GLN LYS SER LYS HIS			
20	25	30	
GLN GLY VAL ARG LYS ALA LYS TRP HIS LEU GLY ILE ARG SER GLN			
35	40	45	
SER ARG PRO ASN ASP ILE MET ALA GLU VAL CYS			
50	55		

(2) INFORMATION FOR SEQ ID NO: 10:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 10

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 10:

ARG PRO ASN ASP ILE MET ALA GLU VAL CYS

1 5 10

(2) INFORMATION FOR SEQ ID NO: 11:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 70

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

- 35 -

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 11:

ARG	ALA	ILE	LYS	GLN	LEU	ASP	TYR	GLU	TRP	LYS	VAL	VAL	ASN	PRO
1									10					15
TYR	TYR	LEU	ARG	VAL	ARG	ARG	LYS	ASN	PRO	VAL	THR	SER	THR	TYR
									20	25				30
SER	LYS	MET	SER	LEU	GLN	LEU	TYR	GLN	VAL	ASP	SER	ARG	THR	TYR
									35	40				45
LEU	LEU	ASP	PHE	ARG	SER	ILE	ASP	ASP	GLU	ILE	THR	GLU	ALA	LYS
									50	55				60
SER	GLY	THR	ALA	THR	PRO	GLN	ARG	SER	GLY					
									65	70				

(2) INFORMATION FOR SEQ ID NO: 12:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 64

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 12:

SER	VAL	SER	ASN	TYR	ARG	SER	CYS	GLN	ARG	SER	ASP	SER	ASP	ALA
1									10					15
GLU	ALA	GLN	GLY	LYS	SER	SER	GLU	VAL	SER	LEU	THR	SER	SER	VAL
									20	25				30
THR	SER	LEU	ASP	SER	SER	PRO	VAL	ASP	LEU	THR	PRO	ARG	PRO	GLY
									35	40				45
SER	HIS	THR	ILE	GLU	PHE	PHE	GLU	MET	CYS	ALA	ASN	LEU	ILE	LYS
									50	55				60
ILE	LEU	ALA	GLN											

(2) INFORMATION FOR SEQ ID NO: 13:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 22

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 13:

ASP GLY ARG VAL LYS ILE GLY HIS TYR ILE LEU GLY ASP THR LEU

1 5 10 15

GLY VAL GLY THR PHE GLY LYS

20

(2) INFORMATION FOR SEQ ID NO: 14:

- 36 -

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 16
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 14:

ASP GLU LYS GLU SER ARG ARG LEU PHE GLN GLN ILE LEU SER GLY
1 5 10 15
VAL

(2) INFORMATION FOR SEQ ID NO: 15:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 33
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 15:

ASP LEU LYS PRO GLU ASN VAL LEU LEU ASP ALA HIS MET ASN ALA
1 5 10 15
LYS ILE ALA ASP PHE GLY LEU SER ASN MET MET SER ASP GLY GLU
20 25 30
PHE LEU ARG

(2) INFORMATION FOR SEQ ID NO: 16:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 13
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 16:

GLU VAL ILE SER GLY ARG LEU TYR ALA GLY PRO GLU VAL
1 5 10

(2) INFORMATION FOR SEQ ID NO: 17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 9

- 37 -

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 17:

XAA MET LEU GLN VAL ASP PRO MET LYS

1 5

(2) INFORMATION FOR SEQ ID NO: 18:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 35

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 18:

LYS ASP ILE ARG GLU HIS GLU XAA PHE LYS GLN ASP LEU PRO LYS
1 5 10 15
TYR LEU PHE PRO GLU ASP PRO SER TYR SER XAA THR MET ILE ASP
20 25 30
ASP GLU ALA LEU LYS
35

(2) INFORMATION FOR SEQ ID NO: 19:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 17

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 19:

XAA XAA GLN ASP PRO LEU ALA VAL ALA TYR HIS LEU ILE ILE ASP

1 5 10 15

ASN ARG

(2) INFORMATION FOR SEQ ID NO: 20:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 9

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

- 38 -

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 20:

ASP PHE TYR LEU ALA THR SER PRO PRO

1 5

(2) INFORMATION FOR SEQ ID NO: 21:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 11

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 21:

ASP SER PHE LEU ASP ASP HIS HIS LEU THR ARG

1 5 10

(2) INFORMATION FOR SEQ ID NO: 22:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 10

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 22:

VAL PRO PHE LEU VAL ALA GLU THR PRO ARG

1 5 10

(2) INFORMATION FOR SEQ ID NO: 23:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 23

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 23:

ASP GLU LEU ASN PRO GLN LYS XAA LYS HIS GLN GLY VAL ARG LYS

1 5 10 15

ALA LYS XAA HIS LEU GLY ILE ARG

- 39 -

20

(2) INFORMATION FOR SEQ ID NO: 24:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 19
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 24:

GLN LEU ASP TYR GLU XAA LYS VAL VAL ASN PRO TYR TYR LEU ARG

1 5 10 15

VAL ARG ARG LYS

(2) INFORMATION FOR SEQ ID NO: 25:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 25
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 25:

LYS MET SER LEU GLN LEU TYR GLN VAL ASP SER ARG THR TYR LEU

1 5 10 15

LEU ASP PHE ARG SER ILE ASP ASP XAA ILE

20 25

(2) INFORMATION FOR SEQ ID NO: 26:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 18
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 26:

ASP ALA GLU ALA GLN GLY LYS SER SER GLU ALA SER LEU THR XAA

1 5 10 15

- 40 -

SER VAL THR

(2) INFORMATION FOR SEQ ID NO: 27:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 17

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 27:

ILE GLY HIS TYR ILE LEU GLY ASP THR LEU GLY VAL GLY THR PHE

1 5 10 15

GLY LYS

(2) INFORMATION FOR SEQ ID NO: 28:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 26

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 28:

LEU TYR GLN VAL ILE SER THR PRO SER ASP ILE PHE MET VAL MET

1 5 10 15

GLU TYR VAL SER GLY GLY GLU LEU PHE ASP TYR

20 25

(2) INFORMATION FOR SEQ ID NO: 29:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 12

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 29:

ARG LEU PHE GLN GLN ILE LEU SER GLY VAL ASP TYR

1 5 10

- 41 -

(2) INFORMATION FOR SEQ ID NO: 30:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 11
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 30:

ASP LEU LYS PRO GLU ASN VAL LEU LEU ASP ALA

1 5 10

(2) INFORMATION FOR SEQ ID NO: 31:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 17
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 31:

ILE ALA ASP PHE GLY LEU SER ASN MET MET SER ASP GLY GLU PHE

1 5 10 15

LEU ARG

(2) INFORMATION FOR SEQ ID NO: 32:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 22
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 32:

LYS ILE XAA ASP GLY ILE PHE TYR THR PRO GLN TYR LEU ASN PRO

1 5 10 15

XAA VAL ILE XAA LEU LEU LYS

20

(2) INFORMATION FOR SEQ ID NO: 33:

- 42 -

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 5
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 33:

ASP ILE ARG GLU HIS

1 5

(2) INFORMATION FOR SEQ ID NO: 34:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 34:

TYR LEU PHE PRO GLU ASP PRO SER TYR SER XAA XAA MET ILE ASP

1 5 10 15

ASP GLU ALA LEU LYS

20

(2) INFORMATION FOR SEQ ID NO: 35:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 16
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 35:

ASN HIS GLN ASP PRO LEU ALA VAL ALA TYR HIS LEU ILE ILE ASP

1 5 10 15

ASN

(2) INFORMATION FOR SEQ ID NO: 36:

(i) SEQUENCE CHARACTERISTICS:

- 43 -

(A) LENGTH: 9

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 36:

ASP PHE TYR LEU ALA THR XAA PRO PRO

1 5

(2) INFORMATION FOR SEQ ID NO: 37:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 9

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 37:

ASP XAA PHE LEU ASP ASP HIS XAA LEU

1 5

(2) INFORMATION FOR SEQ ID NO: 38:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 10

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 38:

VAL PRO PHE LEU VAL ALA GLU THR PRO ARG

1 5 10

(2) INFORMATION FOR SEQ ID NO: 39:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 5

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 39:

- 44 -

TRP HIS LEU GLY ILE

1 5

(2) INFORMATION FOR SEQ ID NO: 40:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 14

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 40:

XAA GLN SER ARG PRO ASN ASP ILE MET ALA GLU VAL XAA ARG

1 5 10

(2) INFORMATION FOR SEQ ID NO: 41:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 10

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 41:

VAL VAL ASN PRO TYR TYR LEU ARG VAL ARG

1 5 10

(2) INFORMATION FOR SEQ ID NO: 42:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 18

(B) TYPE: Amino acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 42:

MET SER LEU GLN LEU TYR GLN VAL ASP SER ARG THR TYR LEU LEU

1 5 10 15

LEU PHE ARG

(2) INFORMATION FOR SEQ ID NO: 43:

- 45 -

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 12
- (B) TYPE: Amino acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 43:

XAA ASP SER ASP ALA GLU ALA GLN GLY LYS PRO SER

1 5 10

(2) INFORMATION FOR SEQ ID NO: 44:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1647
- (B) TYPE: Nucleic acid
- (C) STRANDEDNESS: Single
- (D) TOPOLOGY: Linear

(iv) ANTI-SENSE: No

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 44:

ATGGCCGAGA	AGCAGAAAGCA	CGACGGGCGG	GTGAAGATCG	GCCACTACAT	50
CCTGGGGGAC	ACGCTGGCG	TCGGCACCTT	CGGGAAAGTG	AAGGTGGGCA	100
AGCACGAGTT	GACTGGACAT	AAAGTTGCTG	TGAAGATACT	CAACCGGCAG	150
AAGATTGAA	GCCTGGACGT	GGTCGGGAAA	ATCCGCAGAG	AGATCCAGAA	200
CCTGAAGCTT	TTCAGGCACC	CTCATATAAT	CAAACGTAC	CAGGTCATCA	250
GTACACCGTC	TGATATTTTC	ATGGTCATGG	AATATGTCTC	AGGAGGAGAG	300
CTATTTGATT	ATATCTGTAA	AAATGGAAGG	TTGGACGAAA	AGGAGAGTCG	350
ACGTCTGTT	CAGCAGATCC	TTTCTGGTGT	GGACTATTGT	CACAGGCATA	400
TGGTGGTCCA	CAGAGATTTG	AAACCTGAAA	ACGTCTGCT	TGATGCACAC	450
ATGAATGCAA	AGATAGCCGA	CTTCGGTCTT	TCAAACATGA	TGTCAAGATGG	500
TGAATTTTA	AGAACGAGCT	GTGGCTCGCC	CAATTATGCT	GCACCAGAAAG	550
TAATTTCAGG	AAGATTCTAC	GCAGGCCCTG	AAGTAGACAT	CTGGAGCAGC	600
GGGGTCATTC	TCTATGCTT	GCTGTGTGGA	ACTCTCCCTT	TTGATGATGA	650
CCACGTGCCA	ACTCTTTTA	AGAAGATATG	TGACGGGATA	TTTTATACCC	700
CTCAGTATT	GAATCCCTCT	GTAATAAGCC	TTTGAAAGCA	TATGCTGCAG	750
GTAGATCCTA	TGAAGAGGGC	CACAATAAAA	GATATCAGGG	AACATGAATG	800
GTTTAAGCAG	GACCTTCCAA	AATATCTCTT	TCCTGAAGAC	CCGTCTTATA	850
GTTCAACCAT	GATTGATGAT	GAAGCCTTAA	AAGAAGTGTG	TGAGAAGTTC	900
GAGTGCTCAG	AGGAGGAGGT	CCTCAGCTGC	CTGTACAACA	GAAACCCACCA	950
GGACCCACTG	GCAGTTGCCT	ACCACCTCAT	AATAGACAAC	AGGAGAATAA	1000
TGAACGAAGC	CAAAGATTTC	TACTTGGCAA	CAAGCCCACC	CGATTCTTTC	1050
CTCGATGATC	ACCATTAAAC	TCGGCCTCAC	CCTGAGAGAG	TACCATCTT	1100
GGTTGCCGAA	ACACCAAGGG	CCCGACACAC	CCTAGATGAA	TTAAACCCAC	1150
AGAAATCCAA	ACACCAAGGC	GTACGGAGG	CAAAGTGGCA	TTGGGGATT	1200
CGAAGTCAAA	GCCGACCCAA	TGACATCATG	GCAGAAGTGT	GTAGAGCAAT	1250
CAAGCAGTTG	GACTATGAAT	GGAGGTTGT	AAACCCCTAT	TATTCGCGTG	1300

- 46 -

TGCGAAGGAA	GAACCTGTG	ACAAGCACAT	TTTCCAAAAT	GAGTCTACAG	1350
CTATACCAAG	TGGATAGTAG	GACTTACTTA	TTGGATTTC	GAAGTATTGA	1400
TGATGAGATT	ACAGAAGCCA	AATCAGGGAC	TGCTACTCCA	CAGAGATCGG	1450
GATCCATCAG	CAACTATCGA	TCTTGCCAAA	GGAGCGACTC	CGACGCCGAG	1500
GCTCAAGGAA	AGCCCTCAGA	AGTCTCTCTT	ACCTCATCCG	TGACCTCCCT	1550
CGACTCCTCT	CCTGTTGACG	TAGCTCCAAG	ACCAGGAAGT	CACACGATAG	1600
AATTTTTGA	AATGTGTGCA	AATCTAATTA	AAATTCTTGC	ACAGTAA	1647

(2) INFORMATION FOR SEQ ID NO: 45:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 20

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 45:

ASP PHE TYR LEU ALA THR SER PRO PRO ASP SER PHE LEU ASP ASP

1 5 10 15

HIS HIS LEU THR ARG

20

(2) INFORMATION FOR SEQ ID NO: 46:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 12

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 46:

PRO LEU SER ARG THR LEU SER VAL ALA ALA LYS LYS

1 5 10

(2) INFORMATION FOR SEQ ID NO: 47:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 13

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 47:

- 47 -

LEU LYS LYS LEU THR LEU ARG ALA SER PHE SER ALA GLN
1 5 10

(2) INFORMATION FOR SEQ ID NO: 48:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 14
- (B) TYPE: Amino Acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 48:

PRO GLY LEU LYS PRO HIS PRO GLU ARG MET PRO PRO LEU ILE
1 5 10

(2) INFORMATION FOR SEQ ID NO: 49:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 15
- (B) TYPE: Amino Acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 49:

HIS MET ARG SER ALA MET SER GLY LEU HIS LEU VAL LYS ARG ARG
1 5 10 15

(2) INFORMATION FOR SEQ ID NO: 50:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20
- (B) TYPE: Amino Acid
- (D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 50:

ASP PHE TYR LEU ALA THR SER PRO PRO ASP SER PHE LEU ASP ASP
1 5 10 15
HIS HIS LEU THR ARG

- 48 -

(2) INFORMATION FOR SEQ ID NO: 51:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 15

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 51:

MET ASP ASP SER ALA MET HIS ILE PRO PRO GLY LEU LYS PRO HIS

1 5 10 15

(2) INFORMATION FOR SEQ ID NO: 52:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 17

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 52:

VAL VAL ASP ILE TYR SER LYS PHE ASP VAL ILE ASN LEU ALA ALA

1 5 10 15

GLU LYS

(2) INFORMATION FOR SEQ ID NO: 53:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 19

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 53:

GLY CYS GLY GLY ALA THR CYS CYS GLY THR ASN GLY ALA TYR ALA

1 5 10 15

THR HIS THR ALA

(2) INFORMATION FOR SEQ ID NO: 54:

(i) SEQUENCE CHARACTERISTICS:

- 49 -

(A) LENGTH: 22

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 54:

CYS GLY GLY ALA ALA THR THR CYS TYR THR THR TYR THR CYS ASN

1 5 10 15

GLY CYS ASN GLY CYS ASN ALA

20

(2) INFORMATION FOR SEQ ID NO: 55:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 8

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 55:

LYS PHE ASP VAL ILE ASN LEU ALA

1 5

(2) INFORMATION FOR SEQ ID NO: 56:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 23

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 56:

ALA ALA ARG THR THR TYR GLY ALA TYR GLY THR ASN ALA THR HIS

1 5 10 15

ALA ALA TYR CYS THR ASN GLY CYS

20

(2) INFORMATION FOR SEQ ID NO: 57:

(i) SEQUENCE CHARACTERISTICS:

- 50 -

(A) LENGTH: 23

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 57:

ALA ALA ARG THR THR TYR GLY ALA TYR GLY THR ASN ALA THR HIS

1 5 10 15

ALA ALA TYR THR THR ARG GLY CYS

20

(2) INFORMATION FOR SEQ ID NO: 58:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 23

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 58:

CYS THR CYS CYS ALA ALA GLY THR THR GLY ALA THR GLY THR

1 5 10 15

THR ALA THR CYS ALA ALA CYS CYS

20

(2) INFORMATION FOR SEQ ID NO: 59:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 6

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 59:

GLU GLU LEU GLN ILE GLY

1 5

(2) INFORMATION FOR SEQ ID NO: 60:

(i) SEQUENCE CHARACTERISTICS:

- 51 -

(A) LENGTH: 7

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 60:

PHE PRO LYS PRO GLU PHE MET

1 5

(2) INFORMATION FOR SEQ ID NO: 61:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 1978

(B) TYPE: Nucleic acid

(C) STRANDEDNESS: Single

(D) TOPOLOGY: Linear

(iv) ANTI-SENSE: No

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 61:

CTCGCTGCGG	TCCAAGCAGG	TAAAGCGGGG	CTCGCGAAC	GCGCGCGACC	50
CGAGGGCGT	GGTCCGCGGT	CCCGGGGGTC	CCGGCCCGGC	CCTTCCCGCT	100
TCCCTGTGTC	CCCGCAGACA	CTTCGCCATG	GGCAATACGA	GCAGCGAGCG	150
CGCCGCGCTG	GAGCGGCAGG	CTGCCATAA	GACGCCGCGG	AGGGACAGCT	200
CGGAGGGCAC	CAAGGATGGG	GACAGGCCA	AGATCCTGAT	GGACAGCCCC	250
GAAGACGCCG	ACATCTTCCA	CACCGAGGAA	ATGAAGGCTC	CAGAGAAGGA	300
GGAGTTCCTG	GCGTGGCAGC	ACGACCTCGA	GGTGAATGAG	AAAGCCCCG	350
CCCAGGCTCG	GCCCACCGTA	TTTCGATGGA	CAGGGGTGG	AAAGGAGGTC	400
TACTTGTCTG	GATCCTTCAA	CAACTGGAGC	AAATTGCC	TCACTAGAAG	450
CCAAAACAAC	TTCGTAGCCA	TCCTGGACCT	NCCGGAAGGA	GAGCATCAGT	500
ACAAGTTCTT	TGTGGATGGC	CAGTGGACCC	ACGATCCTTC	CGAGCCAATA	550
GTAACCAGCC	AGCTTGGCAC	AGTTAACAAAC	ATCATTCAAG	TGAAGAAAAC	600
TGACTTTGAA	GTATTTGATG	CTTTAATGGT	GGATTCCCAA	AAGTGTCCG	650
ATGTATCTGA	GCTGTCCAGT	TCCCCCCCAG	GACCCTACCA	CCAGGAGCCT	700
TACATCTCTA	AACCAGAGGA	GCGGTTCAAG	GCCCCGCCA	TCCTCCGCC	750
TCACCTGCTG	CAGGTCACT	TGAACAAAGGA	CACGGGCATC	TCTTGTGATC	800
CAGCGCTGCT	TCCGGAGCCC	AACCACGTCA	TGCTGAACCA	CCTCTATGCA	850
CTCTCTATCA	AGGATGGAGT	GATGGTGCTC	AGTGCACCC	ATCGGTACAA	950
GAAAAAGTAC	GTCACCACCC	TCCTCTACAA	GCCCATATGA	GAGGATGAGC	950
CAGCCGTGGG	CCACGGGACA	GCAGGGGGG	GCCGCTGGG	TCTCCGTGTG	1000
CATGCGCATC	CTCACTCCGG	GACATCTCAC	CCCCACATAG	TCCTCCTTGA	1050
AGGTCTGTCC	AGGCACAGCC	AGAAATCGGA	TGGACGGCAG	ACCGTGGTCC	1100
CAGCACCGCA	GGCAGTGC	CAGGCTCTAG	TGCTCTAAC	ATCATCCCTC	1150
TGCTGGCCCG	AGATGTCTAC	AGCCAGACCT	GAATGCTGGT	TCCTGCTAGA	1200
AAACCTAGGA	CAGGAACGTGA	AGTCACCAAA	GCCCTCATCA	TCCCTGCTGA	1250
AGCCTGGCTT	GGAAGAAAGC	AGTGCTCGGT	CTTGCCGTGTC	CTTCCGAATC	1300
ACAGCAGTAG	ATTGTAGACT	CCATGGAATT	TCAGTGTCCA	ATTTCCAGAT	1350
GCAGCTTCGC	AATCGATTCC	TGACACTGTG	CACTGAGACC	TTCTTAACCA	1400

GAGTGGCTGG	CTGTCACACTC	TCACTTAAGG	CAATAAGTCA	CCAGGACGAG	1450
ACTATAGGTC	ATGTGACTAC	TGAGCAATAA	TCGTTCTCAN	ACAGACATCA	1500
GAAACCACTG	CCATTCTCC	ATCAAGCCAG	ACGATCCTGA	GGACTGACCA	1550
CCATGGGAGG	TTGTCCACCT	TATTCAGTT	GCAGTGGTGG	CCATGTTACC	1600
GTGACAACCT	GGTCGAAGTG	CCCAGCCTCT	TTTTAGTTCT	AGCACGTGCT	1650
ACTCAGCTGG	GGGCGGTGTC	TCCAGTGAGC	AGAGAGTGT	CACGGTGGTT	1700
ACTATTGCCT	GATCCTAAGA	GAGCTGGCA	CCCTGCGGCA	GACTGCTAGG	1750
TTCCAGCAGG	GTTGGCACGA	GTGAACCTAT	GTGTGCTCAG	TGTGATTCC	1800
ACAGTGATGT	CACAGACGTG	CCCATTGGTA	CAGGCTCCTG	TCACCTGTCA	1850
GCATAGGTAG	GCACAAGCTC	TGTGGTGTCC	GCTATTGGT	TAAACCTGAG	1900
TTTTGGGTAC	CTTTGTTAC	TGTTTCAAA	ACACGGACTT	GCTGTCATCT	1950
TGATGTACAA	GTTCATAAA	AGCTTTGG			1978

(2) INFORMATION FOR SEQ ID NO: 62:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 270

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 62:

MET	GLY	ASN	THR	SER	SER	GLU	ARG	ALA	ALA	LEU	GLU	ARG	GLN	ALA
1						5				10				15
GLY	HIS	LYS	THR	PRO	ARG	ARG	ASP	SER	SER	GLU	GLY	THR	LYS	ASP
						20				25				30
GLY	ASP	ARG	PRO	LYS	ILE	LEU	MET	ASP	SER	PRO	GLU	ASP	ALA	ASP
					35					40				45
ILE	PHE	HIS	THR	GLU	GLU	MET	LYS	ALA	PRO	GLU	LYS	GLU	GLU	PHE
					50					55				60
LEU	ALA	TRP	GLN	HIS	ASP	LEU	GLU	VAL	ASN	GLU	LYS	ALA	PRO	ALA
					65					70				75
GLN	ALA	ARG	PRO	THR	VAL	PHE	ARG	TRP	THR	GLY	GLY	GLY	LYS	GLU
					80					85				90
VAL	TYR	LEU	SER	GLY	SER	PHE	ASN	ASN	TRP	SER	LYS	LEU	PRO	LEU
					95					100				105
THR	ARG	SER	GLN	ASN	ASN	PHE	VAL	ALA	ILE	LEU	ASP	LEU	PRO	GLU
					110					115				120
GLY	GLU	HIS	GLN	TYR	LYS	PHE	PHE	VAL	ASP	GLY	GLN	TRP	THR	HIS
					125					130				135
ASP	PRO	SER	GLU	PRO	ILE	VAL	THR	SER	GLN	LEU	GLY	THR	VAL	ASN
					140					145				150
ASN	ILE	ILE	GLN	VAL	LYS	LYS	THR	ASP	PHE	GLU	VAL	PHE	ASP	ALA
					155					160				165
LEU	MET	VAL	ASP	SER	GLN	LYS	CYS	SER	ASP	VAL	SER	GLU	LEU	SER
					170					175				180
SER	SER	PRO	PRO	GLY	PRO	TYR	HIS	GLN	GLU	PRO	TYR	ILE	SER	LYS
					185					190				195
PRO	GLU	GLU	ARG	PHE	LYS	ALA	PRO	PRO	ILE	LEU	PRO	PRO	HIS	LEU
					200					205				210
LEU	GLN	VAL	ILE	LEU	ASN	LYS	ASP	THR	GLY	ILE	SER	CYS	ASP	PRO
					215					220				225
ALA	LEU	LEU	PRO	GLU	PRO	ASN	HIS	VAL	MET	LEU	ASN	HIS	LEU	TYR

- 53 -

230	235	240
ALA LEU SER ILE LYS ASP GLY VAL MET	VAL LEU SER ALA THR HIS	
245	250	255
ARG TYR LYS LYS LYS TYR VAL THR THR	LEU LEU TYR LYS PRO ILE	
260	265	270

(2) INFORMATION FOR SEQ ID NO: 63:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 1576

(B) TYPE: Nucleic acid

(C) STRANDEDNESS: Single

(D) TOPOLOGY: Linear

(iv) ANTI-SENSE: No

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 63:

GC GCC CTTAA	AG ATGGT GAG	GG GGCT ATGC	TCT GAG TAGA	AG GTGGT GAC	50
CT CCAGGAGC	GG TGGGATGA	TG AGGGCCCG	GG GCCTCTT	GCA ATGGAGA	100
CG GTCA TTTC	TTCAGATAGC	TCCCAGCTG	TGG AAAATGA	GC ATCCCTCAA	150
GAG ACCCCAG	AATCCAACAA	TAGCGTGTAT	ACTT CCTTCA	TGA AGTCTCA	200
TC GCTGCTAT	GACCTGATT C	CCACAAGCTC	CAAATTGGTT	GT ATT TGATA	250
CG TCCCTGCA	GGTGAAGAAA	GCTTTTTTG	CTT TGGT GAC	TAACGGTGTA	300
CGAGCTGCC	CTTTATGGGA	TAGTAAGAAG	CAAAGTTTG	TGGGCATGCT	350
GACC ATCACT	GATT CATCA	ATAT CCTGCA	CCGCTACTAT	AAATCAGCGT	400
TGGTACAGAT	CTATGAGCTA	GAAGAACACA	AG ATAGAAC	TTGGAGAGAG	450
GT GTATCTCC	AGGACTCCTT	TAAACCGCTT	GTCTGCATTT	CTCCTAATGC	500
CAGCTTGT TT	GATGCTGTCT	CTTCATTAAT	TCGCAACAA G	ATCCACAGGC	550
TGCCAGTTAT	TGACCCAGAA	TCAGGCAATA	CTTTGTACAT	CCTCACCCAC	600
AAGCGCATT C	TGAAGTTCCT	CAAATTGTTT	ATCACTGAGT	TCCCCAAGCC	650
AGAGTTCATG	TCCAAGTCTC	TGGAAAGAGCT	ACAGATTGGC	ACCTATGCCA	700
ATATTGCTAT	GGTTCGCACT	ACCACCCCG	TCTATGTGGC	TCTGGGGATT	750
TTTGTACAGC	ATCGAGTCTC	AGCCCTGCCA	GTGGTGGATG	AGAAGGGCG	800
TGTGGTGGAC	ATCTACTCCA	AGTTTGATGT	TATCAATCTG	GCAGCAGAAA	850
AGACCTACAA	CAACCTAGAT	GTATATGTGA	CTAAAGCCTT	GCAACATCGA	900
TCACATTACT	TTGAGGGTGT	TCTCAAGTGC	TACCTGCATG	AGACTCTGGA	950
GACC ATCATC	AACAGGCTAG	TGGAAGCAGA	GGTT CACC GA	CTTGTAGTGG	1000
TGGATGAAA	TGATGTGGTC	AAGGGAATTG	TATCACTGTC	TGACATCCTG	1050
CAGGCCCTGG	TGCTCACAGG	TGGAGAGAAG	AAGCCCTGAG	CTGGGGAAAGG	1100
GGTCATGCAG	CACCAGGGGA	TATGCCCAAC	TC ACTGCCTG	CTGGAAGCTC	1150
TGTGGGAATC	AGATGAAACT	TGAGGGAATT	GTGACTCTGT	TCCCTGTTCA	1200
GGGTCCCCTG	CCCTTCTATC	TGGGAGCTAG	GGAAGGTATG	GGGGAGGAAA	1250
GAGAATGGAT	TTATAGCTAC	CCTTACCCCTC	ACACATACAC	TTGAAAAAAC	1300
TTTCAGCCTA	GCCAGTTCTA	GCCCCTGTCC	TCTT TAGATAT	ATCCCCCTTT	1350
CTGGGTGAAC	TATAGGCTCT	GTGCCTCTCA	GACA ATTCT	GATCTCTAAC	1400
AGATCCCCAG	ACCTCACTTG	CCTCTGCCTC	CATCTGGCC	CTGATTCAAC	1450
CCTAAGATAA	TAGCACAACAA	AAATTCTTCA	TAAAGATATT	TTTATTCAACC	1500
TGTTCCGTGC	TATATGGAGG	AGGCCAAGTC	CATTTAGTGA	CATTTCTTCC	1550
CATAATGTGA	GTGGGGAGGA	TTGTGG			1576

(2) INFORMATION FOR SEQ ID NO: 64:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 331

(B) TYPE: Amino Acid

(D) TOPOLOGY: Linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 64:

PRO

What is Claimed is:

1. A nucleic acid sequence encoding mammalian AMPK α_1 .
2. The nucleic acid sequence of claim 1 comprising SEQ ID NO: 44.
- 5 3. A vector comprising a nucleic acid sequence of claim 1.
4. A host cell comprising a vector of claim 3.
5. A recombinant polypeptide encoded by the nucleic acid sequence of claim 1.
- 10 6. A method of producing mammalian AMPK α_1 comprising:
 - (a) culturing cells of claim 4 under conditions which allow expression of the nucleic acid sequence encoding mammalian AMPK α_1 ; and
 - (b) recovering the expressed AMPK α_1 from the cell.
- 15 7. An oligonucleotide probe comprising at least 10 nucleotides, said oligonucleotide probe being capable of selectively hybridizing to a nucleic acid sequence of claim 1.
- 20 8. A substantially purified polypeptide or biologically active fragment thereof encoded by a nucleic acid sequence of claim 1.
9. An antibody capable of binding selectively to a polypeptide of claim 8.
- 25 10. A nucleic acid sequence encoding mammalian AMPK β , said nucleic acid sequence comprising SEQ ID NO: 61.
11. A vector comprising the nucleic acid sequence of claim 10.

- 56 -

12. A host cell comprising a vector of claim 11.
13. A recombinant polypeptide encoded by the nucleic acid sequence of claim 10.
14. A method of producing mammalian AMPK β comprising:
 - 5 (a) culturing cells of claim 12 under conditions which allow expression of the nucleic acid sequence encoding AMPK β ; and
 - (b) recovering the expressed AMPK β .
15. A substantially purified polypeptide comprising an 10 amino acid sequence of SEQ ID NO: 62.
16. A nucleic acid sequence encoding mammalian AMPK γ , said nucleic acid sequence comprising SEQ ID NO: 63.
17. A vector comprising the nucleic acid sequence of claim 16.
- 15 18. A host cell comprising a vector of claim 17.
19. A recombinant polypeptide encoded by the nucleic acid sequence of claim 16.
20. A method of producing mammalian AMPK γ comprising:
 - 20 (a) culturing cells of claim 18 under conditions which allow expression of the nucleic acid sequence encoding AMPK γ ; and
 - (b) recovering the expressed AMPK γ .
21. A substantially purified polypeptide comprising an amino acid sequence of SEQ ID NO: 64.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/00270

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : C07K 2/00, 14/47, 16/18; C12N 5/10, 15/09, 15/11, 15/12, 15/63, 15/70, 15/74, 15/79

US CL : 435/69.1, 320.1, 325, 252.3, 254.11; 530/300, 350, 387.1, 412; 536/23.5, 24.31

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 435/69.1, 320.1, 325, 252.3, 254.11; 530/300, 350, 387.1, 412; 536/23.5, 24.31

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, STN (MEDLINE, INPADOC, EMBASE, CAPLUS, WPIDS)

search terms: AMP, protein kinase?, alpha?, beta?, gamma?, 5' AMP, AMPK, stapleton d?/au, mitchellhill k?/au, witters l?/au

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---, P	WOODS, A. et al. Characterization of AMP-activated protein kinase beta and gamma subunits. J. Biol. Chem. 26 April 1996. Vol. 271, No. 5, pages 10282-10290, especially page 10283 and Fig. 1-2.	10-15 -----
Y	CARLING D. et al. Mammalian AMP-activated protein kinase is homologous to yeast and plant protein kinases involved in the regulation of carbon metabolism. J. Biol. Chem. 15 April 1994. Vol. 269, No. 15, pages 11442-11448, especially page 11444 and Fig. 3.	16-21
X ---, P	STAPLETON D. et al. Mammalian AMP-activated protein kinase subfamily. J. Biol. Chem. 12 January 1996. Vol. 271, No. 2, pages 611-614, especially page 612.	1-3, 7-9 ----- 5,6
Y		1,2,7-9 ----- 3-6

Further documents are listed in the continuation of Box C.

See patent family annex.

Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reasons (as specified)	*A*	document member of the same patent family
D document referring to an oral disclosure, use, exhibition or other means		
P document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

07 APRIL 1997

Date of mailing of the international search report

25 APR 1997

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Authorized officer

CLAIRE M. KAUFMAN

Patent Office

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/00270

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BERI R.K. et al. Molecular cloning, expression and chromosomal localisation of human AMP-activated protein kinase. FEBS Lett. 1994. Vol. 356, pages 117-121.	1,7,9
X	WO 94/28116 A (ZENECA LIMITED) 08 December 1994, see entire document.	1,3-9
X	STAPLETON D. et al. Mammalian 5'-AMP-activated protein kinase non-catalytic subunits are homologs of proteins that interact with yeast Snf1 protein kinase. J. Biol. Chem. 25 November 1994. Vol. 269, No. 47, pages 29343-29346, especially bottom of 1st col.	1,15
X	MITCHELHILL K.I. et al. Mammalian AMP-activated protein kinase shares structural and functional homology with the catalytic domain of yeast Snf1 protein kinase. J. Biol. Chem. 28 January 1994. Vol. 269, No. 4, pages 2361-2364, especially Fig. 1.	8
X	YANG X. et al. A family of proteins containing a conserved domain that mediates interaction with the yeast SNF1 protein kinase complex. EMBO J. 1994. Vol. 13, No. 24, pages 5878-5886, especially Fig. 2.	15
X	GAO G. et al. Catalytic subunits of the porcine and rat 5'-AMP-activated protein kinase are members of the SNF1 protein kinase family. Biochim. Biophys. Acta. 1995. Vol. 1266, pages 73-82, especially pages 74-76.	1-3,7
A	CELENZA J.L. et al. Molecular analysis of the SNF4 gene of <i>Saccharomyces cerevisiae</i> : Evidence for physical association of the SNF4 protein with the SNF1 protein kinase. Mol. Cell. Biol. November 1989. Vol. 9, No. 11, pages 5045-5054.	1-9,16-21
A, P	PIOSIK P.A. et al. Carpine homologue of rodent 5'-AMP-activated protein kinase subunit and yeast SNF4/CAT3 is down-regulated by thyroid horomone. Mol. Brain Res. 1996. Vol. 40, pages 240-253.	16-21
A	AGUAN K. et al. Characterization and chromosomal localization of the human homologue of a rat AMP-activated protein kinase-encoding gene: a major regulator of lipid metabolism in mammals. Gene. 1994. Vol. 149, pages 345-350.	1-7

INTERNATIONAL SEARCH REPORT

International application No. PCT/US97/00270

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DALE S. et al. Similar substrate recognition motifs for mammalain AMP-activated protein kinase, higher plant HMG-CoA reductase kinase-A, yeast SNF1, and mammalian calmodulin-dependent protein kinase I. FEBS Lett. 1995. Vol. 361, pages 191-195.	1-8
A, P	DYCK J.R.B. et al. Regulation of 5'-AMP-activate protein kinase activity by the noncatalytic beta and gamma subuints. J. Biol. Chem. 26 July 1996. Vol. 271, No. 30, pages 17798-17803.	10-21
A	VERHOEVEN A.J.M. et al. The AMP-activated protein kinase gene is highly expressed in rat skeletal muscle. Eur. J. Biochem. 1995. Vol. 228, pages 236-243.	1-7
A, P	MICHELL B.J. et al. Isoform-specific purification and substrate specificity of the 5'-AMP-activiated protein kinase. J. Biol. Chem. 08 November 1996. Vol. 271, No. 45, pages 28445-28450.	1-21

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/00270

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.: because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest



The additional search fees were accompanied by the applicant's protest.



No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US97/00270

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I, claims 1-8, drawn to nucleic acid encoding AMPK alpha1 polypeptide, oligonucleotide, vector, host cell, polypeptide, and method of producing polypeptide.

Group II, claim 9, drawn to antibody.

Group III, claims 10-15, drawn to nucleic acid encoding AMPK beta polypeptide, oligonucleotide, vector, host cell, polypeptide, and method of producing polypeptide.

Group IV, claims 16-21, drawn to nucleic acid encoding AMPK gamma polypeptide, oligonucleotide, vector, host cell, polypeptide, and method of producing polypeptide.

The inventions listed as Groups I-IV do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: The nucleic acid, polypeptide, vector, host cell, and method of Groups I, III, and IV do not share a special technical with each other because each group relates to different AMPK subunits (alpha1, beta, and gamma, respectively) that do not share structure or function. Additionally, Groups I, III, and IV do not share a special technical feature with the antibody of Group II because that antibody does not share structure or function with the other products and cannot be made by or used in any of the claimed methods.